* System units

[1] international system (SI)

- distance (metre)
- mile = 1609 m
- force (Newton) or Kg m/sec
- Power (watt) or N·m/sec
- mass (Kg).
- tonne = 1000 Kg
- acceleration of gravity $g = 9.81 \ m/sec^2$
- velocity m/sec or mile.p.h

* British system

- distance (ft)
  inch = 2.54 cm
  Yd = 3 ~~inch~~ feet
  Foot = 12 inch
  mile = 1760 yd
  = 5280 ft
- force (Ib.wt)
- power (Ib.wt.ft per sec)

* mass (pound weight) (Ib)

1 tons = 2240 (Ib.wt)

: acceleration of gravity (32.2 ft/sec²)

- velocity (ft/sec)

: torque produced by Motors:

$$T_m = T_L + T_f + J\frac{d\omega}{dt}$$

$T_1 \Rightarrow$ عزم الحمل

T_f = عزم الدوران الناشئ عن الاحتكاك

$J\frac{d\omega}{dt}$ عزم القصور الذاتي

وهو العزم المسبب للتسارع الزاوي ويتلاشى عند الدوران بسرعة منتظمة

$$T_m = T_L + T_f$$

$$\boxed{v = \omega \cdot r}$$

* Types of Motors used in Electric traction

[1] dc Motors

تتميز بأنها تدور بالسرعة المطلوبة بدقة

ذات مدى واسع لتغيير السرعة

- امكانية عكس اتجاه حركتها الدورانية

- تعطي عزم بدء حركة مناسب

[2] Induction Motors

- Squirrel Cage rotor مناسبة للتطبيقات التي تحتاج لسرعة دوران ثابتة

- wound rotor 〃 〃 〃 〃 عزم بدء كبير مع تقليل من حدة تيار البدء

[3] Synchronous Motors

مناسب للتطبيقات التي تحتاج سرعة دوران ثابتة تقريبية

ومقدرات كبيرة، امكانية تصميمها عند سرعات منخفضة لعامل

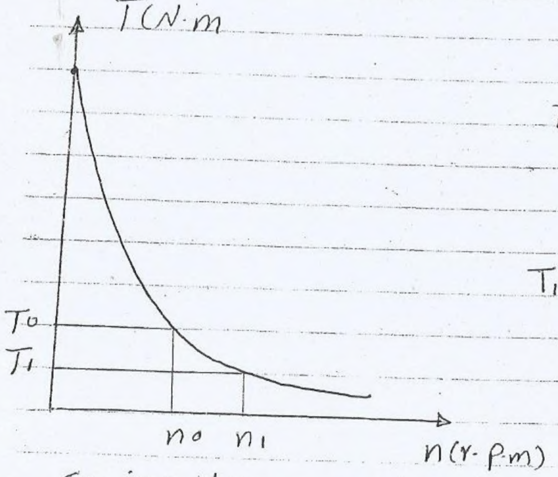
قدرة عالي وكفاءة تشغيل مرتفعة

* general chis of Electric traction Motors:

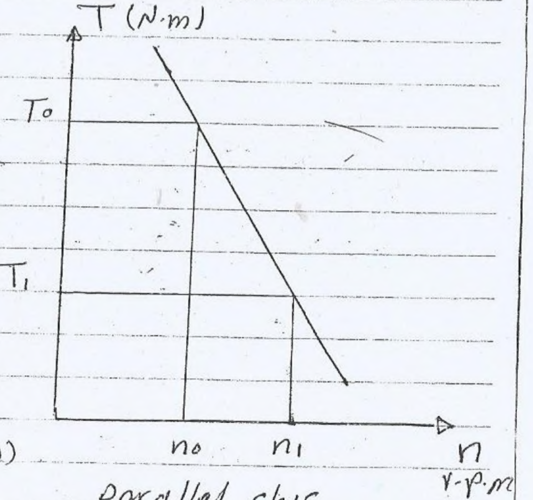
a) High Starting torque

للتغلب على الإعارية وللاعمل على إيشارع المطلوب

b) Series ch's between torque and Speed



Series ch's



parallel chis

. لو كان هناك محركين متماثلين ولكن نظراً للاختلاف كل أحدهم يدور
بسرعة أعلى من الآخر ولتكن n0 , n1

1. إذا كان المحركين لهما خصائص التوازي كان أن الفارق من العزم كبير
فالمحرك الذي تكون سرعته أعلى تكون ذو عزم صغير وعليه
لن يتم توزيع الحمل can fairly

2. إذا كان لهما خصائص التوالي كان الفارق من العزم صغير وبالتالي
هناك توزيع متساوي للحمل على المحاور
ولذلك يفضل المحرك series عند الأحمال الكبيرة كذلك يستخدم عادة كالاتي $T \alpha 1/n$
مقدمه ازد

(c) easy to control in speed

d) has ability to using electric breaking.

e) " " " standing suddenly change in voltage

(f) " " Standing cutting off source of supply
تحمل الانقطاع المؤقت لمصدر الجهد
لأنه Eb تكون قد انخفضت كثيراً عن قيمتها الأولى مما يسبب
مرور تيار كبير بالمحرك

(g) hardness, weight and volume
كبير القياس وزن المحرك يجر قدر الإمكان لسهولة تغطيته
ولسهولة حركته وصغر الإمكان للخفض لتثبيته

* System of electric traction

Can be divided according to getting their power to main groups.

(a) Vehicles generate its own Energy and subdivided according to the nature of generation or storage

diesel [illegible] - electric train or ships
- petrol electric trucks, lorries
- the battery-driven road vehicles

(b) vehicles recieve their power from distributing network fed by a few large generating stations

- dc station } tramways - rail ways
- ac station } trolley buses طالحسب نوع الماكينة

* types of power supply used in electric traction.

(a) dc Current System

600 - 700v (tram) داخل المدينة
1500 - 3000v (trolley) خارج المدينة

(b) Single phase system

11 - 15 Kv with $f = 16\frac{2}{3}$ (Hz) or 25 Hz

تحتوي على كويل خافض 300-400 ويستخدم التردد المنخفض.

لتحسين الكفاءة ، p.f وتحسين الشرارة الكهربائية بين الموحد والفرش

وتقليل X وبالتالي تقليل الفقد في الجهد . وتقليل التداخل بين الشبكات

(c) three phase system.

3.3 Kv $f = 16\,2/3$ Hz

ليتم خفض هوائيات والتخفيض هو الحمل الثالث مع تغير

أسباب التردد

* Advantges of Electric traction.

1- it is a cleanliness so it essential for use in underground and tube railways
النظافة التي تتناسب المحرك الكهربائي
2- rapid & smooth acceleration and braking
يعتمد على التي يبعثه من السرعة
3- have a large speed than steam traction electric
traction → 1-20 Mph
steam.t → 0.4 → 0.5 M.Ph
4- easy to stop specially in frequent stops
سهل التوقف أو الفرملة خصوصاً مع تكرار التوقف عن الخط
والقطار.
5- need less time for maintenance and repair so less cost to maintanence and repair by 50%

6- Can carry more people than steam traction because of higher average speed.
نتيجة لدوران عالي بالنسبة لشارع فيصبح زيادة حمل الأكثر.

7- it can be used immediatly at any time it connected to supply so better utilization

8- No smoke or sparks and no damage to building due to smoke fumes so it is safety

9- Saving in cost and energy due to absence of coaling and water depots (خزانات التبريد) and also time of coaling of engines.

10- the electric braking method is better than mecanical breaking due to

- less wear on brake shoes
- less heat wasted in the brake shoes

* Didsadvantges of E.T.

1- High cost required to convert from steam to electric traction due to over head equipement and feeders.
تكاليف انشاء عالية

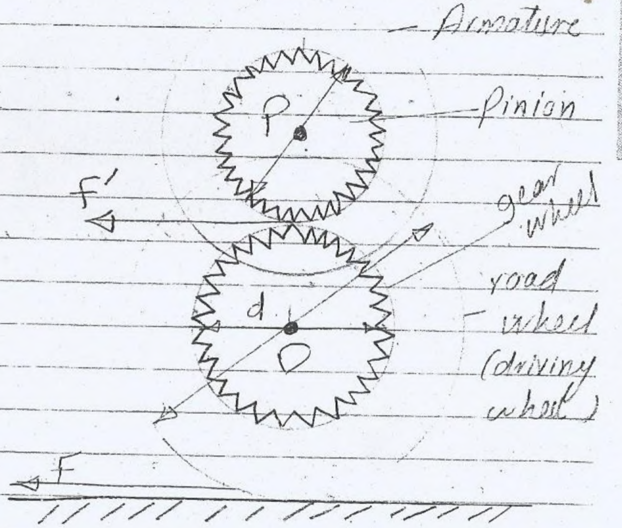
2- failure in power supply for afew minites may cause cut off servies for hours so increase reliability of supply

3- Formation of ice layers on conductor rails will prevent the train to get it's power, this can be overcome by runing a service locomotive up and down the line to prevent Ice formation

4- the interferance between the power line with telephone and telegraph lines runs along the track So high cost for moving lines away the tracks or replaced by cable.

5- require a power for heating the Compartments at high cost
تدفئة

* Mechanices of train movement:



$$T = F' * \frac{P}{2}$$

$$F' = \frac{2T}{P}$$

gear efficiency

$$\eta = \frac{F D/2}{F' d/2}$$

$$\eta = \frac{F}{2T}\left(\frac{P}{d}\right) D$$

$G = d/P$ gear ratio

$$\eta = \frac{F}{2T}\frac{1}{G} D \Rightarrow F = \eta 2T \frac{G}{D}$$

$$F_t = \eta T * \left(\frac{2G}{D}\right) \quad \#$$

tractive effort on driving wheel

driving wheel (D) تنتقل الى tractive effort = F'

gear wheel (d)

η_{ad} (cofficient of adhesion) $= \frac{\text{tractive effort to slip the wheel}}{\text{adhesive weight}}$

معامل الالتصاق

وزن العربية

Speed m.p.h	0	10	20	30	40	50
τ_{ad}	0.25	0.16	0.14	0.12	0.10	0.09

if rails are greasy (مشحم) the value is 0.08

Ex/ if train has weight m (tons) and third of weight is driving wheel
what the max acceleration of τ_{ad} 0→0.25

Solution.

$\tau_{ad} = F/W$ $\quad F = \tau_{ad} W$

$m * a = \tau_{ad}\, m * g$

$a = \tau_{ad} * g$

$= 0.25 * 32.2 = 8.1$ Ft/sec/sec

$= 8.1 \dfrac{0.3 * 0.62 * 3600}{1000}$ mile/h/sec

$a = 5.5$ m.p.h.p.s

max acceleration

$a = 5.5 * 1/3 = 1.83$ m.p.h.p.s

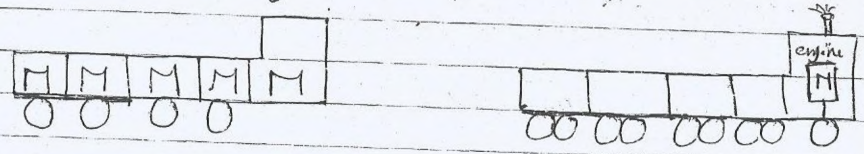
- For steam traction the adhesive weight less than 50%

τ_{ad} (electric traction) > τ_{ad} (steam traction)

- this is because:

1- the torque in electric traction is continous while in steam traction is pulsating.

2- in E.T the driven wheels are distributed along the length of train while in steam traction they are close together.



* Tractive effort required to move the train

$F_t = F_a + F_r \pm F_g$

F_a the required T.Eff for linear acceleration
القوة اللازمة للتسارع الخطي

F_r the required T.Effort to overcome the train resistance
للتغلب على قوة المقاومة لحركة القطار

F_g the required T.Effort to overcome the acceleration of gravity + صعود
− نزول

• Fa calculation:

if a force (fa) (Ib.wt) acts on a mass of ω (tons) the acceleration is (a):

$$a = \frac{Fa}{m} = \frac{Fa}{(\omega/g)} = \frac{Fa\,(32.2)}{2240\,\omega} \rightarrow \text{Ft/sec/sec} \quad \frac{5280}{3600}$$

$$a = \frac{Fa}{\omega}(0.01437) * \frac{0.3*0.62}{1000} * 3600 \quad \text{m.p.h.p.s}$$

$$\boxed{Fa = 102\,\omega\,a}$$

Ib.wt   tons   m.p.h.p.s

- when train accelerates K.E is produced in 2 ways

① Linear motion of the train

② rotation of wheel and motors.

$$K.E_t = K.E_{Linear} + KE_{rotation}$$

$$= \frac{1}{2}\overset{m}{\omega}V^2 + \sum \frac{I}{2}\omega^2, \quad \omega = V/r$$

$$= \frac{1}{2}\overset{m}{\omega}V^2 + \frac{I}{2}\sum\left(\frac{V}{r}\right)^2$$

$$= \frac{1}{2}\overset{m}{\omega}V^2 + \frac{1}{2}V^2 \sum \frac{I}{r^2} \rightarrow m \text{ (rotating mass)}$$

$$= \frac{1}{2}\overset{m}{\omega}V^2 + \frac{1}{2}mV^2$$

$$K.E = \frac{1}{2}(\omega + m)V^2$$

$$\boxed{K.E = \frac{1}{2}\omega_e V^2}$$

where

ω = dead weight

ω_e = effective weight or accelerating mass of the train

I = moment of inertia of rotating parts

m = 8 → 15 % of ω

* tractive effort to overcome the train resistance.

$$\boxed{Fr = \omega . r} \quad \text{(Ib.wt)}$$

r = specific train resistance (Ib.wt/ton)

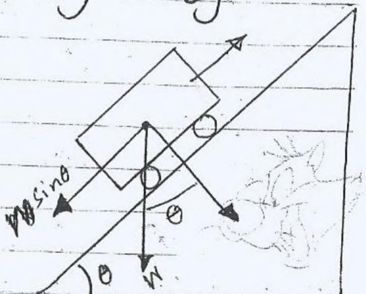
القوة المقاومة لحركة القطار وتشمل القوى التي تعاكس الحركة

① المقاومات الميكانيكية مثل الاحتكاك (تعتمد على كتلة القطار)

② مقاومة الرياح وهي تتناسب مع مربع سرعة القطار

* tractive effort to overcome the gravity

$$Fg = \pm \omega \sin\theta$$



if G النسبة المئوية للميل

لو $G = \frac{Y}{X}$ الأفقي

$G\% = \left(\frac{y}{x}\right) * 100 = G'$

$G\% = 100 \sin\theta = G'$

$\sin\theta = \frac{G'}{100}$

$Fg = \pm w * \frac{G'}{100}$ tons

$Fg = \pm w \frac{G'}{100} * 2240 \rightarrow Ib$

$Fg = \pm 22.4\, w\, G'$ (Ib.wt)   w → tons

$Ft = 102\, wea + wr \pm 22.4\, w\, G'$ (Ib.wt)

tons, m.ph.ps, ton, Ib.wt/ton, ton, $\frac{y}{x} * 100$

- the output power of the driving axies

$P = Ft\, V$ Ib.wt.ft/sec

if V in (m.p.h)

$P = Ft * V \left(\frac{5280}{3600}\right)$ Ib.wt.ft/sec

$1\ h.p = 550$ Ib.wt ft/sec

$P = ft.V \left(\frac{5280}{3600 * 550}\right)$ (h.p)

$1 h.p = 746\ w$

$P = ft * V \left(\frac{5280 * 746}{3600 * 550 * 1000}\right)$ (Kw)

$P = 0.002\, ft.V$ kw

Ib.wt   m.p.h

* in (SI) system.

$Fa = me.a$ ⇒ Newton

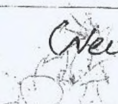
⇒ me → Kg , a → m/sec^2

$Fa = me(1000) * a\left(\frac{1000}{3600}\right)$

$fa = 277.8\, me.a$ Newton

Km/h/sec   ~~Kg~~ tonne

$Fr = m(tonne) * r\ (Newton/tonne) = m.r$ (Newton)



$fg = \pm mg \sin\theta = 1000 \times 9.81\, m \frac{c}{100} = 98.1\, m.c$

$$\boxed{F_t = 277.8\, m_e \cdot a + m \cdot r \pm 98.1\, m \cdot G} \quad (N)$$

m_e: tonne, a: km/h/s, r: Newton/tonne, m: tonne

$G = \frac{y}{x} * 100$

* the required Power:

- if V in (m/sec)

$$P_o = F_t \cdot V \quad (\text{watt})$$

- if V in (Km/h)

$$P_o = F_t \cdot V \left(\frac{1000}{3600}\right) \quad (\text{watt})$$

$$= F_t \cdot V \left(\frac{1000}{3600 * 1000}\right) \quad (\text{Kw})$$

$$\boxed{P_o = \frac{F_t \cdot V}{3600}} \quad (\text{Kw})$$

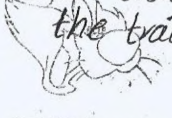
F_t: Newton, V: Km/h

EX: a motor coach train weighing 200 tons is accelerate up a gradiant of 1 in 200 at a mean acceleration of 1.2 m.p.h.p.s up to speed of 30 m.p.h find

(1) tractive effort required

(2) the out put at the end of the accelerating period

the train resistance 10 Ib/ton and We = 10%



Solution.

$a = 1.2$ m.p.h.p.s , $W = 200$ ton , $W_e = 200 + \frac{10}{100} * 200$

$W_e = 220$ tons, $r = 10$ Ib/ton

$$G = \frac{1}{200} * 100 = 0.5$$

$$F_t = 102\, W_e \cdot a + W \cdot r + 22.4\, W\, G$$

$$= 102 * 220 * 1.2 + 200 * 10 + 22.4 * 200 * 0.5$$

$$F_t = 31168 \quad (\text{Ib.wt})$$

(2) at the end of acceleration V=30 the power required

$$P_o = 0.002\, F_t \cdot V \quad (\text{Kw})$$

$$= 0.002 * 31168 * 30$$

$$P_o = 1860 \text{ Kw}$$

*****

[2] train weight 240 tonne, accelerate up gradient 1:250 of a mean acceleration 2 km/hour/sec, until the velocity reach to 60 km/h find

1. Tractive effort
2. the power required if $r = 50$ N/t , $W_e = 1.1W$

Solution

$a = 2$ Km/h/sec, $m = 240$ tonne

$me = 1.1 * 240 = 264$ tonne

$r = 50$ N/t , $C = \frac{1}{250} * 100 = 0.4\%$

$$Ft = 277.8\, me \cdot a + m \cdot r + 98.1\, m \cdot c$$

$$= 277.8 * 264 * 2 + 240 * 50 + 98.1 * 240 * 0.4$$

$$= 168096 \quad (N)$$

$$Po = \frac{Ft \cdot v}{3600} = \frac{168096 * 60}{3600} = 2802 \text{ KW}$$

* a train has weighing 250 tonne, run with 4 Motors accelerate up gradient 1:80 and take 20 sec to reach 42 km/sec if Gear ratio 3.5 and $\eta = 92\%$ $r = 40$ N/t , and $We = 1.1\, W$, $D = 92$ cm

* find the torque produced by each Motor

Solution.

$$a = \frac{V}{t} = \frac{42}{20} = 2.1 \text{ Km/h/sec}$$

$$me = 1.1 * 250 = 275 \text{ tonne}$$

$$c = \frac{1}{80} * 100 = 1.25\%$$

$$Ft = 277.8\, me \cdot a + m \cdot r + 98.1\, m \cdot c$$

$$Ft = 277.8 * 275 * 2.1 + 250 * 40 + 98.1 * 250 * 1.25$$

$$= 201054.5 \text{ N}$$

$$Ft = \frac{2 \eta G_i}{D} Tm$$

$$201054.5 = 2 * 0.92 * \frac{3.5}{0.92} * Tm$$

$$Tm = \frac{201054.5 * 0.92}{2 * 0.92 * 3.5} = 28722 \text{ N.m}$$

$$\text{Torque/Motor} = \frac{28722}{4} = 7180 \text{ N.m}$$

* train weight 250 tonne move with 4 Motors each produce torque equal 8000 N.m, up gradient 30:1000 If gear ratio 3.5 and $\eta = 90\%$, $r = 50\,N/t$ $W_e = 1.1W$ and $D = 90\,cm$ find ⟹
- time required to reach 80 km/h
- if $V = 3000$ volte, $\eta = 85\%$ for motor find the Current

Solution

$$F_t = 2\eta \frac{G\,T_m}{D}$$

$$= 2 * 0.9 * \frac{3.5}{0.9} * 4 * 8000 = 224000\ N$$

$$C = \frac{30}{1000} * 100 = 3\%$$

$$F_t = f_a + f_r + f_g \Rightarrow$$

$$224000 = F_a + 250*50 + 98.1*250*3$$
$$= F_a + 86075$$

$$F_a = 137925 \quad (N)$$

$$F_a = 277.8\,m_e * a = 137925$$

$$a = \frac{137925}{277.8\,m_e} = \frac{137925}{277.8*1.1*250} = 1.8\ km/h/sec$$

$$t = \frac{V}{a} = \frac{80}{1.8} = 44.44\ sec$$

$$\eta_m = \frac{P_o}{P_{in}} \Rightarrow P_{in} = \frac{P_o}{\eta}$$

$$= \frac{F_t \cdot V}{\eta * 3600} \ (kW) = \frac{224000*80}{0.85*3600} = 5856\ kW$$

$$\text{total Current} = \frac{5856000}{3000} = 1952 \quad (A)$$

$$\text{Current / Motor} = 1952/4 = 488 \quad (A)$$

* Types of Service for people carrying with E.T.

أنواع خدمات نقل الركاب بالجر الكهربائي

1. City Service. داخل المدينة

حيث تكون المواقف متقاربة تقريبا كل 1 كيلومتر ومعدل التسارع والتباطؤ ضروري لتحقيق سرعة جدولية متوسطة بين محطات التوقف

2. Suburban city service. ضواحي المدينة

حيث تكون مسافة الوقوف ٢-٥ كيلومتر والمسافة الكلية 30-40km

ومعدل التسارع، التباطؤ ضروري

3. main line service. لنقل بين المدن

تكون المسافة طويلة والوقفات قليلة ومعدل التسارع والتباطؤ غير ضروري والسرعات العالية مرغوب فيها

* Speed time Curves:

- there are 2 curves:

[1] Speed time curve — الأهم

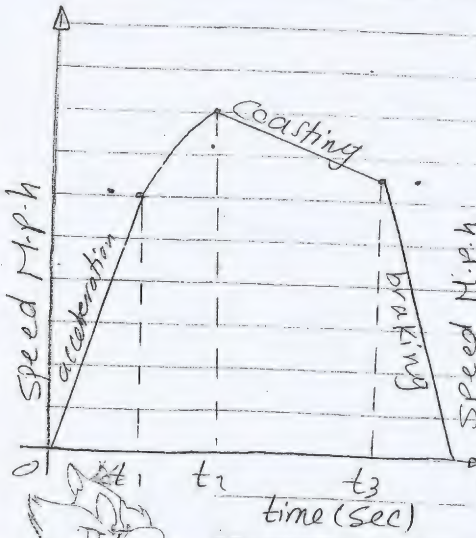
[2] distance-speed curve

- the importance of speed-time curve when we study the motion of train is:

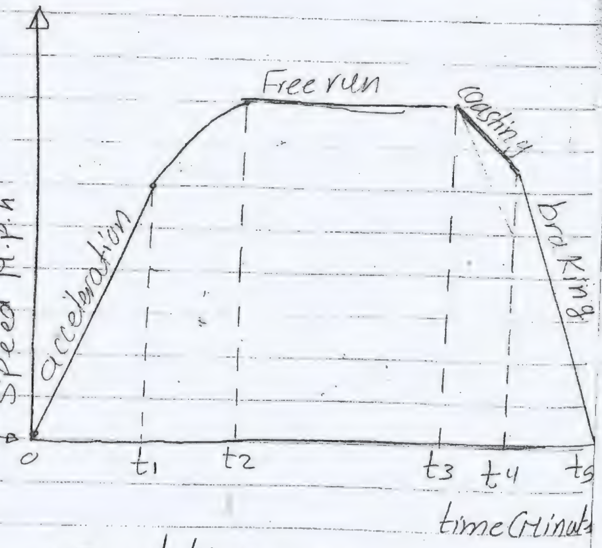
1- يمكن قراءة السرعة مباشرة عند أي لحظة زمنية

2- ميل المماس يعطي التسارع والتباطؤ عند تلك اللحظة

3- المساحة المحصورة تحت المنحنى يساوي كقيمة لقطع المسافة



* speed-time curve in city service.



* Speed-time curve in main line service

1- فترة التسارع الثابت $(0-t_1)$: يبذل المحرك فيها عزم كبير لازمة للحفاظ على التسارع الثابت

2- فترة التسارع على السرعة (t_1-t_2): من خلال هذه الفترة يتناقص التسارع تدريجيا حتى يتساوى القدرة المتولدة مع المقاومة عندها تصبح السرعة ثابتة ~~محددة~~ (V_2)

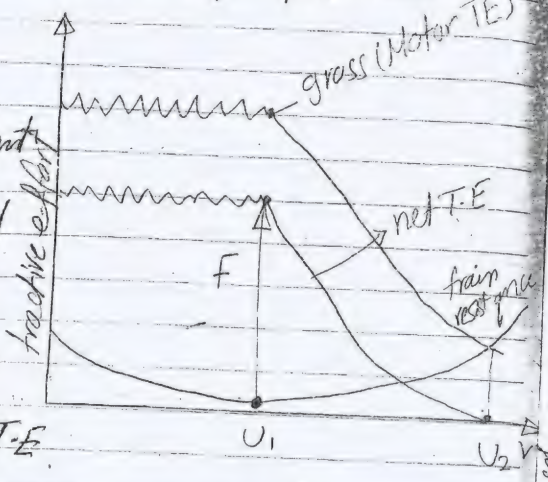
3- فترة الانطلاق الحر (t_2-t_3): يسير القطار بسرعة ثابتة بالقدرة التي وصل اليها من نهاية فترة التسارع

4- فترة الانسياب (t_3-t_4): يتم فصل المحركات عن مصدر التغذية ويتحرك بفعل القصور الذاتي فتبدأ السرعة تدريجيا في الانخفاض إلى مستوى معين نتيجة للمقاومة لحركة القطار حيث تبدأ فترة الفرامل للاستفادة من K.E الموجودة من الكتلة الدوارة بدل من أن تضيع في الفرامل

5- فترة الفرامل (t_4-t_5): فرملة القطار باستخدام فرامل كهربائية أو فرامل ميكانيكية.

* The acceleration Period Consist of 2 Part:-

[1] the first part:-



- the motor T.E kept Constant this occure until all the resistance are switched out at speed (U_1)
- the tractive effort avaliable for acceleration is (f) and it is the different between motor T.E and train resistance
- the acceleration is this periode is nearly constant

[2] the second part:-

- the tractive effort falls rapidly with speed and train resistance increase slowly and then rapidly untile (V_2) where motor T.E = train resistance so the net tractive effort available for acceleration is zero

$V_2 \Rightarrow$ max possible speed.

① Crest speed:- max speed attained on the Run

② average speed:- the mean speed from start to stop

$$V = \frac{S}{T} = \frac{\text{mile}}{}$$

مسافة / زمن — المسافة بين المحطتين / الزمن الفعلي للسير

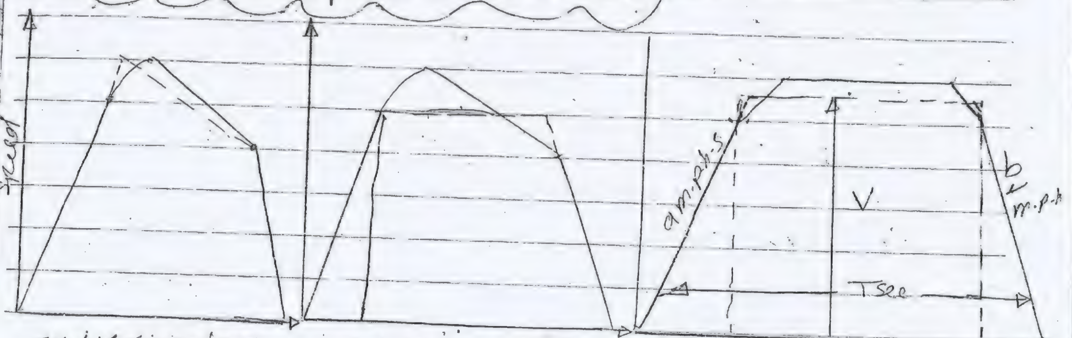
③ Schedule speed:- mean speed when stop periode is included

زمن الوقوف

$$V = \frac{S}{T + T_{stop}}$$

- main line has crest speed 56 m.p.h

* Simplified speed time curves:-



city service quadrilateral — city service trapezoidal — $\leftarrow t_a \rightarrow \leftarrow t_c \rightarrow \leftarrow t_b$ main line service trapezoidal

- speed time curve for city service can be replaced by quadrilateral or trapezodial fig
- the main line service speed time curve replaced by trapezodial fig.

* for main line service prove that

$$V = \frac{1}{2K}\left[T - \sqrt{T^2 - 14400\,SK}\right]$$

where

$$K = \frac{1}{2a} + \frac{1}{2b}$$

a: uniform acceleration in m.p.h.p.s

b: uniform braking in m.p.h.p.s

V: crest speed in m.p.h

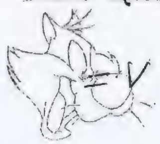
S: distance to run in (mile)

T: time in sec

* Prove *

- duration of acceleration $(t_a) = V/a$
- " " braking $(t_b) = V/b$
- distance of acc $= \frac{1}{2} V t_a = \frac{1}{2}\frac{V^2}{a}$
- " " braking $= \frac{1}{2} V t_b = \frac{1}{2}\frac{V^2}{b}$
- distance of free run or coasting $= V T_c$

$$= V(T - t_a - t_b) = \left(T - \frac{V}{a} - \frac{V}{b}\right) V$$



$$= VT - \frac{V^2}{b} - \frac{V^2}{a}$$

total distance $= \frac{V^2}{2b} + \frac{V^2}{2a} + VT - \frac{V^2}{a} - \frac{V^2}{b}$

$$S' = VT - V^2\left(\frac{1}{2a} + \frac{1}{2b}\right) \quad \frac{\text{mile}}{3600} * 3600$$

a, b in m.p.h.p.s, V = m.p.h, T in sec

$S' = \frac{\text{mile}}{h * \cancel{\text{sec}}} * \text{sec}$ ← hours [illegible]

$S' = \frac{\text{mile}}{3600\,\cancel{\text{sec}}} * \cancel{\text{sec}} \Rightarrow$ ~~[illegible]~~

if we want the distance in miles (S say)

$\frac{S'}{3600} = S$ or: $\boxed{S' = 3600\,S}$

[illegible] 3600 [illegible] mile [illegible] S [illegible] $\frac{\text{mile}}{3600}$ [illegible] S' [illegible] 3600 [illegible] mile/3600

$S = S'/3600$

↓ mile

$$3600\,S = VT - V^2\left(\frac{1}{2a} + \frac{1}{2b}\right)$$

$$3600\,S = VT - KV^2$$

$$KV^2 - VT + 3600\,S = 0$$

$$V = \frac{T \pm \sqrt{T^2 - 4 * 3600\,S K}}{2K}$$

$$\underset{\text{m.p.h}}{V} = \frac{1}{2K}\left(\overset{\text{sec}}{T} \pm \sqrt{T^2 - 14400\,\overset{\text{mile}}{S}K}\right)$$

$$T_c = T - t_a - t_b = T - \frac{V}{a} - \frac{V}{b} = T - V\left(\frac{1}{a} + \frac{1}{b}\right)$$

$$T_c = T - 2KV$$

$$2KV = T \pm \sqrt{T^2 - 14400K}$$

$$T_c = T - \left(T \pm \sqrt{T^2 - 14400K S}\right)$$

$$T_c = \mp \sqrt{T^2 - 1400 S K}$$

[illegible] هنا نأخذ الإشارة الموجبة لأنه

لا يوجد زمن سالب.

$$\underset{+ve}{T_c} = T - 2KV = \pm \sqrt{T^2 - 14400KS}$$

لكي تكون مقدار T_c موجب نأخذ (+)

وعليه كل المعادلة الأخرى بإشارة سالبة

$$2KV = T - \sqrt{T^2 - 14400KS}$$

$$V = \frac{1}{2K}\left[T - \sqrt{T^2 - 14400KS}\right]$$

Ex) $V = 38$ m.p.h, maximum runing speed of the average distance between stops is 2200 yd the scheduale speed instanding a station stop of 20 sec is 25 m.p.h find the necessery acceleration allowing a maximum retardation of 2.5 m.p.h.ps.

$S = 2200$ yd $= 1.25$ miles

$V_{sh} = 25$ m.p.h , $t_{stop} = 20$ sec

time of travel include stop time $= \frac{S}{V} = \frac{1.25}{25} = 0.05$ hr

$T = 3$ minute $= 180$ sec

time of travel $= T - T_{stop} = 180 - 20 = 160$ sec.

$$KV^2 - VT + 3600S = 0$$

$$K = \frac{VT - 3600S}{V^2} = \frac{1}{2a} + \frac{1}{2b}$$

$$\frac{1}{a} = \frac{2}{V^2}\left(VT - 3600S\right) - \frac{1}{b}$$

$$\frac{1}{a} = \frac{2}{38^2}\left(38 \times 160 - 3600 \times 1.25\right) - \frac{1}{2.5}$$

$$1/a = 1.76 \Rightarrow a = 0.57 \text{ m.p.h.ps}$$

Sheet

[1] Two stops per mile ⇒ Distance $S = 0.5$ mile

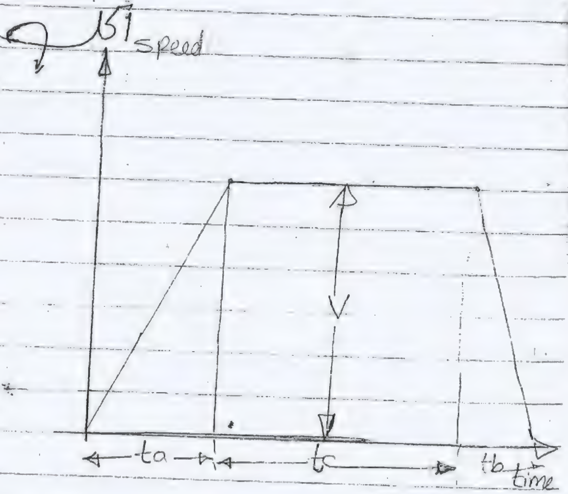
Schedule speed 17 [m.p.h]

Time of stop $t_s = 20$ [sec]

acceleration $= 1.2$ [m.p.h.p.s]

braking retardation $b = 2$ [m.p.h.p.s]

* Determine the trapezoidal speed time curve?



$$V_{schedule} = \frac{S}{T + t_s}$$

$$17 = \frac{0.5}{T + 20}$$

$T + 20 = 0.0294$ hr

$T + 20 = 105.88$ Sec

$T = 85.88$ Sec

$$V = \frac{1}{2K}\left[T - \sqrt{T^2 - 14400 SK}\right]$$

$$K = \frac{1}{2a} + \frac{1}{2b} = \frac{1}{2*1.2} + \frac{1}{2*2} = 0.66$$

$$V = \frac{1}{1.33}\left[85.88 - \sqrt{(85.88)^2 - 14400 * 0.5 * 0.66}\right]$$

$V = 26.06$ [m.p.h]

$$t_a = \frac{V}{a} = \frac{26.06}{1.2} = 21.7 \text{ [sec]}$$

$$t_b = \frac{V}{b} = \frac{26.06}{2} = 13 \text{ [sec]}$$

$t_c = T - t_b - t_a = 51$ [sec]

[2] distance between stops = 1 mile

Schedule speed = 25 [m.p.h]

Time of stop (t_s) = 20 [sec]

braking retardation = 2.25 [m.p.h.p.s]

$$\frac{\text{max speed}}{\text{average speed}} = 1.25$$

* Assuming a trapezoidal speed time curve and Calculate the acceleration.

$V_{sch} = 25$ m.p.h

$$25 = \frac{S}{T + t_s}$$

$$T + 20 = \frac{1}{25} = 0.04 \text{ [hr]}, \quad T = 124 \text{ [sec]}$$

$$V_{av} = \frac{\text{Distance of Run}}{\text{time of Run}} = \frac{1}{124} = 0.00806 \ \text{M.P.S}$$

$$V_{av} = 29.03 \ \text{m.p.h}$$

$$\frac{V_{max}}{V_{av}} = 1.25 \Longrightarrow V_{max} = 1.25 * V_{av}$$

$$V_{max} = 1.25 * 29.03 = 36.3 \ \text{m.p.h}$$

$$V_{max} = \frac{1}{2K}\left[T - \sqrt{T^2 - 14400\, SK}\right]$$

$$36.3 = \frac{1}{2K}\left[124 - \sqrt{(124)^2 - 14400 * 1 * K}\right]$$

$$72.6K = 124 - \sqrt{15376 - 14400K}$$

$$(72.6K - 124)^2 = \left(-\sqrt{15376 - 14400K}\right)^2$$

$$(72.6K)^2 - 2 * 72.6 * 124K + 124^2 = 15376 - 14400K$$

$$5270.76K^2 - 18004.8K + \cancel{15376} = \cancel{15376} - 14400K$$

$$5270.76K^{\cancel{2}} - 3604.8\cancel{K} = 0$$

$$K = \frac{3604.8}{5270.76} = 0.683$$

$$K = \frac{1}{2a} + \frac{1}{2b} = \frac{1}{2a} + \underbrace{\frac{1}{2 * 2.25}}_{0.22}$$

$$\frac{1}{2a} = K - 0.222 = 0.461$$

$$2a = 2.169 \Longrightarrow a = 1.08 \ [\text{m.p.h.p.s}]$$

$\boxed{3}$ $V_1 = 25$ m.p.h , $t_a = 20$ sec , $t_c = 40$ [sec]
$T = 70$ sec. (city service)

$b_c = 0.1$ [m.p.h.s]

Determine the distance run from start to stop and the average speed. (Trapezoidal)
أو (quadrilateral)

$$T = t_a + t_b + t_c = 70 \text{ sec}$$

$$t_b = T - t_a - t_c = 70 - 20 - 40 = 10 \text{ sec}$$

S_T = total distance of the Run

$$= S_a + S_b + S_c$$ مساحة شبه منحرف

$$= \frac{1}{2} t_a V_1 + \frac{1}{2} t_b V_2 + \frac{1}{2} t_c (V_2 + V_1)$$

$V_2 = V_1 - b_c t_c$ # $b_c = \frac{V_1 - V_2}{t_c} \Rightarrow V_1 - V_2 =$

$$V_2 = 25 - 40 * 0.1$$

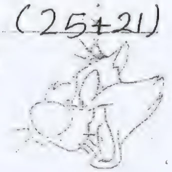
$$V_2 = 21 \ \text{m.p.h}$$

Slope $= b_c = \frac{V_1 - V_2}{t_c}$

$V_2 = V_1 - b_c t_c$

$$S_T = 1/2 * \frac{20}{3600} * 25 + \frac{1}{2}\frac{10}{3600} * 21 + \frac{1}{2} * \frac{400}{3600}(25 + 21)$$

$$S_T = 0.354 \ \text{mile}$$

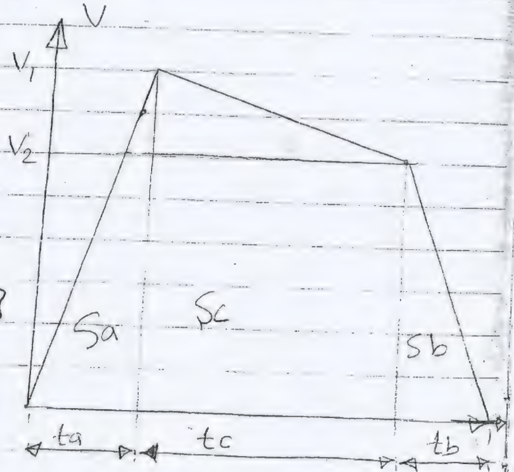


$$V_{av} = \frac{S_T}{T} = \frac{0.354}{70 \text{ sec}} = 18.2 \ \text{m.p.h}$$

21) $S = 1.2$ miles, $V_{sch} = 25$ m.p.h, $t_s = 20$ sec
Coasting retardation $= 0.1$ m.p.h s
Braking retardation $= 2$ m.p.h.s

$V_1 = 38$ m.p.h $= U_{max}$

assume quadrilateral speed-time curve and Determine
a) the acceleration
b) duration of coasting period



$V_{sch} = \frac{S}{T+ts} = 25$

$T+20 = \frac{1.2}{25} = 0.048$ hr

$20+T = 172.8$ [sec]

$T = 152.8$ sec

$\tan\theta = 0.1 = \frac{U_1 - U_2}{tc}$

$S_T = Sa + Sb + Sc$

$= \frac{1}{2} ta U_1 + \frac{1}{2} tb U_2 + \frac{1}{2} tc (U_1 + U_2)$

but $ta = \frac{U_1}{a}$, $tb = \frac{U_2}{b}$, $tc = T - ta - tb$

$U_2 = U_1 - 0.1 tc$ #

$U_2 = b\,tb$

$2tb = U_1 - 0.1 tc$ ($U_1 = 38$ [m.p.h])

$tb = 19 - 0.05 tc$

$T = ta + tb + tc$

$ta = T - tb - tc$

$= 152.8 - 19 + 0.05tc - tc$

$ta = 133.9 - 0.95 tc$

$S_T = \left[\frac{1}{2}(133.9 - 0.95tc) * 38 + \frac{1}{2}(19 - 0.05tc)(38 - 0.1tc) + 0.5\,tc(76 - 0.1tc)\right]$

$= \frac{1}{7200}\left[5810.2 + 36.1\,tc - 0.095 tc^2\right]$

$8640 = 0.095 tc^2 + 36.11\,tc - 5810.2$

$tc^2 - 380\,tc + 29787.4 = 0$

$tc = \frac{380 \pm \sqrt{(380)^2 - 4 * 29787.4}}{2*1}$

$tc = 190 \pm 79.75$

$tc = 269.45$ or 110.55 sec

at $t_c = 110.55$ sec

$t_a = 133.9 - (0.95 \times 11) = 28.45$ [sec]

$V_2 = 38 - (0.1 \times 111) = 26.9$ [m.p.h]

$a = \dfrac{V_1}{t_a} = \dfrac{38}{28.45} = 1.335$ [m.p.h.p.s]

5 $S = 1$ miles, $V_{avg} = 25$ m.p.h, $a = 1.25$ m.p.h.s

Coasting retardation = 0.1 m.p.h.p.s
Braking retardation = 2 m.p.h.p.s

assume quadrilateral speed time curve and Determine
1) the duration of acceleration period
2) " " " coasting "
3) " " " Braking "
4) distance run during these periods.

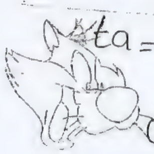
$U_{avg} = \dfrac{S_T}{T} = 25$ [m.p.h]

$T = \dfrac{1}{25} = 0.04$ [hr]

$T = 144$ [sec]

$U_2 = U_1 - t_c b_c$

$U_2 = U_1 - (T - t_a - t_b) b_c$



$t_a = \dfrac{U_1}{a}, \quad t_b = \dfrac{U_2}{b}$

$U_2 = U_1 - \left(T - \dfrac{U_1}{a} - \dfrac{U_2}{b}\right) b_c$

$U_2 = U_1 - \left(T b_c - \dfrac{U_1}{a} b_c - \dfrac{U_2}{b} b_c\right)$

$U_2 = U_1 - T b_c + \dfrac{U_1}{a} b_c + \dfrac{V_2}{b} b_c$

$U_2 \left(1 - \dfrac{b_c}{b}\right) = U_1 \left(1 + \dfrac{b_c}{a}\right) - T b_c$

$U_2 \left(1 - \dfrac{0.1}{2}\right) = U_1 \left(1 + \dfrac{0.1}{1.25}\right) - (144 \times 0.1)$

$0.95 U_2 = 1.08 U_1 - 14.4$

$U_2 = 1.137 U_1 - 15.2$

$S_T = S_a + S_b + S_c$

$= \dfrac{1}{2} \left[t_a U_1 + t_c (V_1 + V_2) + t_b V_2\right]$

$1 = \dfrac{1}{7200} \left[\dfrac{U_1^2}{a} + (U_1 + U_2)\left(T - \dfrac{U_1}{a} - \dfrac{U_2}{b}\right) + \dfrac{U_2^2}{b}\right]$

$7200 = \cancel{\dfrac{U_1^2}{a}} + U_1 T - \cancel{\dfrac{U_1^2}{a}} - \cancel{\dfrac{U_1 U_2}{b}} + U_2 T - \dfrac{U_1 U_2}{a} - \cancel{\dfrac{U_2^2}{b}} + \cancel{\dfrac{V_2^2}{b}}$

$= U_1 T + U_2 T - U_1 U_2 \left(\dfrac{1}{a} + \dfrac{1}{b}\right)$

$= 144 U_1 + 144 (1.137 U_1 - 15.2) - U_1 \times 1.3 \times (1.137 U_1 - 15.2)$

$= 144 U_1 + 163.7 U_1 - 2188.8 - 1.48 V_1^2 + 19.76 U_1$

$7200 = 327.5 U_1 - 2188.8 - 1.98 U_1^2$

$0 = 327.5 U_1 - 9388.8 - 1.98 U_1^2$

$U_1^2 - 221.3 U_1 + 634.0 = 0$

$$U_1 = \frac{221.3 \pm \sqrt{(221.3)^2 - 4 * 6343.8}}{2}$$

$$U_1 = \frac{221.3 \pm 153.6}{2}$$

$$U_1 = 110.65 \pm 76.8$$

$\times$ $U_1 = 188$ [m.p.h] or $U_1 = 33.85$ [m.p.h]

$$U_2 = (1.137 * 33.85) - 15.2$$

$U_2 = 23.3$ [m.p.h]

$t_a = \frac{U_1}{a} = \frac{33.85}{1.25} = 27$ [sec]

$t_b = \frac{U_2}{b} = \frac{23.3}{2} = 11.63$ [sec]

$t_c = T - t_b - t_a = 144 - 27 - 11.65 = 105.35$ [sec]

$S_a = \frac{1}{2} t_a U_1 = 0.5 * 27 * 33.85 = 0.126$ [mile]

$S_b = \frac{1}{2} t_b U_2 = 0.5 * 11.65 * 23.3 = 0.037$ [mile]

$S_c = S_T - S_a - S_b$

$= 1 - 0.126 - 0.037 = 0.836$ [mile]

* Calculation of speed time Curve.

- the attractive effort available for acceleration

$$F_a = F_T - F_r - F_g$$

$$102\, W_e a = F_T - W r \pm 22.4\, W G'$$

$$a = \frac{1}{102\, W_e}\left[F_T - W r \pm 22.4\, W G'\right]$$

r, F_T is a function in speed so if a is a simple function we can integrated it to give ($t - v$) relation as

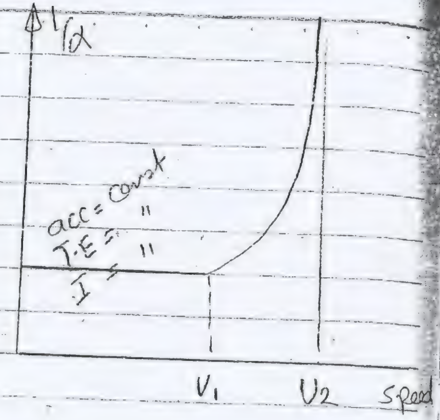
$$a = \frac{dv}{dt} \Rightarrow t = \int \frac{1}{a}\, dv \quad \#$$

- the above equation gives the time at a certain speed under varying acceleration.

during coasting and braking a and dv are negative.

لو كانت a صعب تكاملها مش لاقي لعيش وقتها

- $\frac{1}{a}$ is approximatly const up to speed v_1
- $\frac{1}{a}$ increase to ∞ at speed v_2.

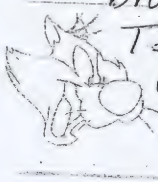


عند رسم العلاقة بين $\frac{1}{\alpha}$ ، V المساحة
تحت المنحنى تعطى الزمن اللازم لأي سرعة.
وعليه يمكننا إيجاد قيمة t عند أي سرعة نريدها،
. acceleration من منحنى (Speed-time)

(Ex) atrain has total weight of 116 tons and has four motor each of 275 h.p

Current. (A)	100	200	300	400	500
speed (m.p.h)	51	31.4	26.4	23.9	22.1
T.E (Ib.wt)/motor	390	1600	2960	4330	5690
train resistance Ib/ton	10	10	10	10	10

- the ratio of effeitive weight to dead weight is 1.1 Imean = 425 A per motor braking retardation is b = 2 m.p.h.ps , S = 0.86 T = 115 sec , Gi = 0.119 train resistance during Coasting is 10 Ib.wt/ton , find Irms Permotor.



« Solution »

- Draw (T.E - Current), (Speed-Current) curves.
- as shown in fig (1).
- the current not allowed to exceed 425A (meancurre
so that the T.E max /motor is 4650 Ib.wt
at speed 23.5 m.p.h. (from drawing).
- $F_g = +22.4\ w\ G_i$

$$= 22.4 * 0.119 * 116 = 310 \quad (Ib.wt)$$

$r = \text{const} \Rightarrow F_r = \text{const}$

- find F_T, F_r, F_g, $1/a$ against speed.

speed	23.5	26	28	30	35	40	45
F_T ($4*F_m$)	18400	12800	10000	7600	5000	3400	2200
F_r	1160						
F_g	310						
F_a	16930	12374	8530	6130	3530	1930	730
a	1.3	0.955	0.656	0.47	0.27	0.148	0.056
1/a	0.767	1.1	1.52	2.12	3.68	6.7	17.8

to find F_t:

- from drawing at speed we can find Fmotor then we multiplying $F_m * 4$

to find a:-

$$F_a = 102 \, W_e \, a$$

$$a = \frac{F_a}{102 W_e}$$

$$a = \frac{F_a}{13000} \quad (m.p.h.p.s)$$

- then find $\frac{1}{a}$

- Draw $\frac{1}{a}$ with V.

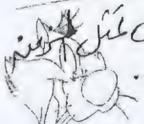
the acceleration is constant at speed $V_1 = 23.5$

$$\frac{1}{a}\Big|_{23.5} = 0.767$$

- to Draw speed time Curve:-

$$a = \frac{dv}{dt}, \quad dt = \frac{1}{a} dv, \quad t = \int \frac{1}{a} dv$$

لما نرسم العلاقة بين (V، $\frac{1}{a}$) فإن المساحة تحت المنحنى تمثل الزمن



at $N = 23.5$ $\quad t = 23.5 * 0.767 = 18$ sec

at $N = 26$ $\quad t = 18 + \frac{1}{2}(1.1 + 0.767) * 2.5 = 20.3$ sec

at $N = 30$ $\quad t = 20.3 + \frac{1}{2}(1.1 + 2.12) * 4 = 26.74$ sec

speed	0	23.5	26	30	35	40
time	0	18	20.3	26.74	41.24	67.19

* to Draw braking curve (we draw straight line with slope = 2)

- From T = 115 sec draw line with slope = 2

* to Draw coasting line.

- supplying is off so the force is friction force and gravity force.

$$F_a = 0, \quad F_T = -F_r - F_g = 102 \, W_e \, b_c$$

$$b_c = \frac{-F_r - F_g}{102 W_e} = \frac{-1160 - 310}{102 * 1.1 * 116} = -0.113 \text{ m.p}$$

- we can not know the end of acceleration and starting of coasting so there are 2 ways:-

① given distance of run.

$1mm^2 = 0.5\ m.p.h \times \frac{1}{3600}$ hour

$1mm^2 = \frac{1}{7200}$ mile

the total distance can be represented by

$$\frac{0.86}{1/7200} = 6192\ mm^2$$

لابد المساحة تحت المنحنى تساوى $6192 mm^2$

ناخذ خط ميله 0.113 عند أى سرعة ونحسب المساحة

كده.

$S = 0.5(115+92)\times 10 = 520\ mm^2$

- at 20 m.p.h

$S = 0.5(115+82)\times 20 = 985\ mm^2$

at 30 m.p.h

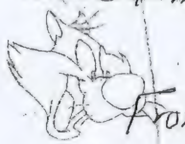
$S = 0.5(115+62)\times 30 = 1327.5\ mm^2$

at 35 m.p.h

$S = 0.5(115+45)\times 35 = 1450\ mm^2$

at 37 m.p.h

$S = 1530\ mm^2$



From this point (37 m.p.h) Drawline with slope 0.113

② given $t_b = 15$ sec.

وعليه نرسم خط ميله 0.113 من زمن 100 sec فصاعدا

على coasting line

* Plot (I-t) curve.

at $t > 45$ sec $\Rightarrow I = 0$. نهاية الـ acceleration

at $V = V_2 = 36$ m.p.h بداية coasting

find I from fig(1)

$I = 175$ (sec)

at $V = V_1 = 23.5$ لأنه I ثابت لغاية V_1

$I = 19$ (sec)

$$I_{rms} = \sqrt{\frac{1}{T}\int i^2 dt}$$

$$= \sqrt{\frac{1}{115}\left[(425^2 \times 19) + 0.5(45-19)(425^2+175^2)\right]}$$

179

3431875 160625 30625

2746250

53722

$I_{rms} = 230$ A

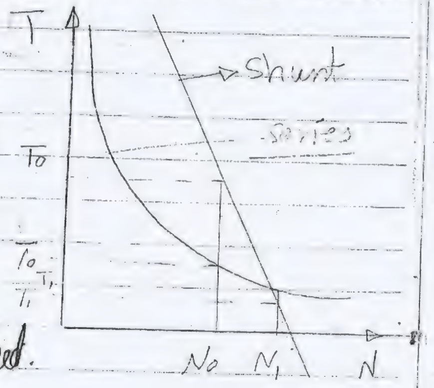
Traction motors

- divided to:

1. DC Motors
   - Series
   - Compound
2. AC Motors
   - 1-Ø I.m
   - 3-Ø I.m

* why Series or Compound motor most used in traction than shunt motor.

1. the series motor or Compound have a torque-speed ch/s that show a rapid variation of speed with torque while the shunt motor has a small variation of speed with torque.



2. $N \alpha \frac{1}{r}$, $N = \frac{V}{r}$ = rotating speed.

at high speed shunt motor may be Run as generator -ve torque produced.

* Starting and speed control of DC motor.

- speed of dc motor can be varied by:

[1] Varying the field.

a. by tapping on the field.

b. by shunt resistance across it "field weakening"

[2] Varying voltage applied.

a- Series resistance method (notching)

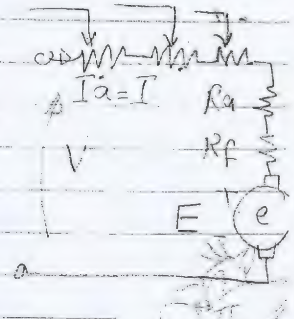
b- Series parallel method

c- metadyne

d- word leonard system (not used in E-T)

(a) Notching:

the Current in Series motor given



$E = V - IR_T$, $R_T = R_a + R_f + R_{ex}$

$I = \frac{V}{R_T + KN}$, $E = KNI$

at $N = 0$ => $I_{st} = \frac{V}{R_T}$ where R_T is small so I_{st} is large.

So external resistance is inserted to limited $\underline{\underline{I}}$ and we decrease Rex gradually so until it go out of Circuit the the current is

$$I = \frac{V}{K_1 N + R_a + R_f}$$

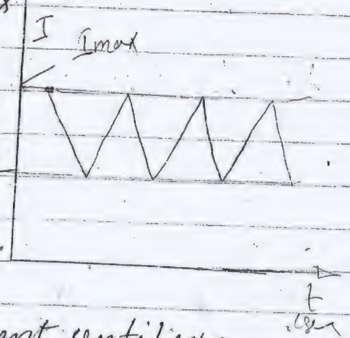
- the current has a min & max value.

at $N = 0$ $\quad I = I_{max} = E/R$

$N = N_1$ $\quad I = I_{min}$

$N = N_2$ $\quad I = I_{max}$ (R reduced)

$N = N_3$ $\quad I = I_{min}$



in this way we divided the current until we reach to full speed.

- disadvantqes.
- cupper loss
* decrease speed
- limitting current
* advantqes.
- easy to use, simple
- reduce starting current, $Pf = 1.0$

- في البداية تكون المقاومة كبيرة في الدائرة وذلك لعمل Limited للتيار وتثبيته عند Imax. بعد ذلك ستزيد سرعة الموتور ويقل التيار إلى Imin ثم أخرج جزء من المقاومة وعليه يزيد التيار إلى Imax بعد ذلك تزداد السرعة فيقل التيار فنخرج المقاومة تدريجيا حتى يتم إخراج المقاومة بالكامل من الدائرة

[2] Series-parallel Control (to decrease Copperloss)

- in this method we deal with 2 motor

1. the 2 motor can be started in series with starting resistance until half speed and then the series resistance is zero so $E_1 + E_2 = V$ $\quad (0 \to N/2)$

2. motor switched into parallel with limitting resistance again until full speed so

$$E_1 = E_2 = V \qquad (N/2 \to N)$$

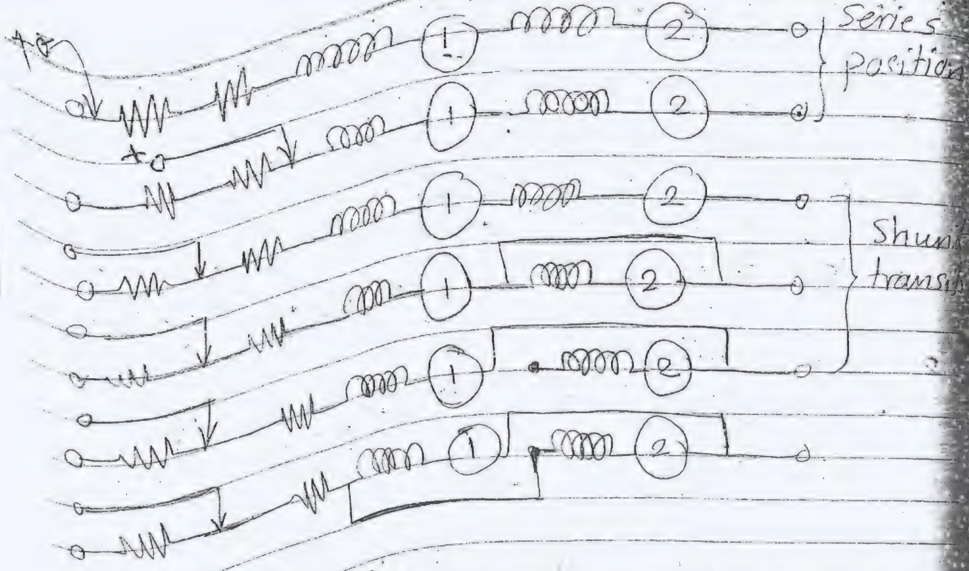
- there are 2 method for transition from series to parallel.

[1] shunt transition:

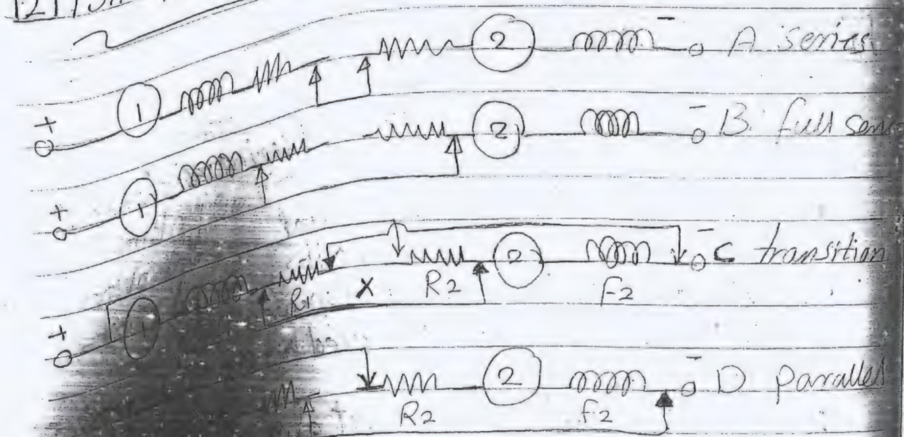
1. the motor runing at N/2 and series resistance is out
2. Some resistance is reinserted
3. one motor is short circuit
4. this motor has one end opened.
5. then this end is connected across so that motors are in parallel.
6. the series resistance is out of circuit.

* disadvantqes.

1. there is a jerk in the system as one motor is shorted and another jerk when reinserted due to K.E in motor.

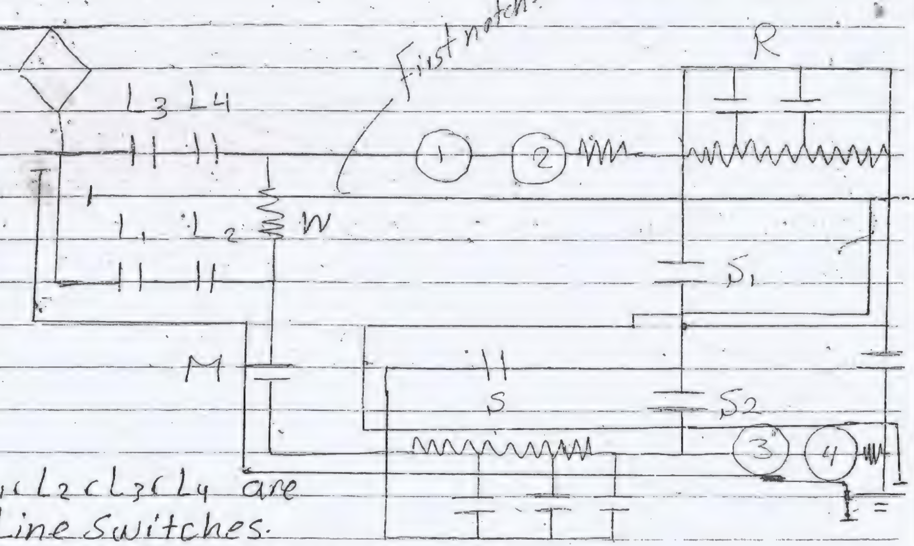


2 Bridge transition.



if the bridge is balance by choosing avalue of (R1, R2) No current pass in branch (X) So the transition is smooth and there is no Jerk.

Simplified form of the Power diagram a 1500 volt dc train equipment.



- L1, L2, L3, L4 are Line Switches.
- S1, S2, S Contactor R
- W is resistance to protect the system at switch on in case there is a fault in motor 1.

* on the first notch.
  L1, L2, S closed then L3, L4 closed the motors are in series.
* S1, S2 closed & S open. motors still in series
* Contactor R then open & M, P are closed S1, S2 are open so the motors are in parallel

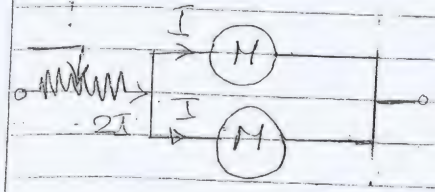
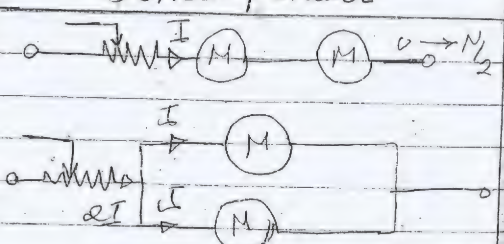
. with full Limitting resistance.

Energy Saved By series parallel control:

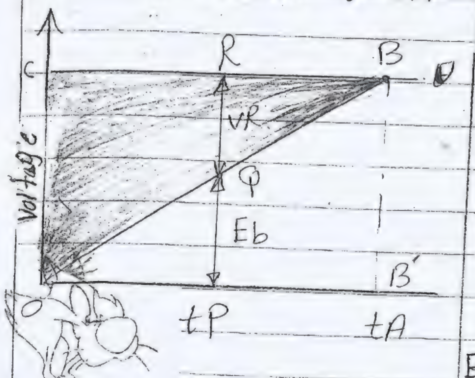
- there are 2 cases:

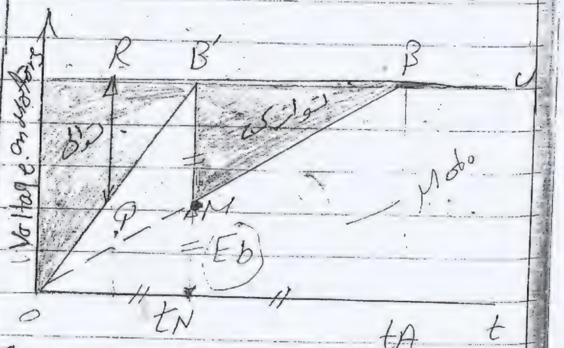
1. motors started in parallel with limiting resistance
2. motors started with series and parallel method.

- in both cases we assume that the series limiting R are continous varied so current in each motors equal to the max value whether in series or parallel so motors produce a constant torque
- neglect armature and field resistance.

Parallel notching.	Series-parallel
	

- the speed and back emf increase with time until $E = V$ at $t = tA$ ($N/2 \to N$)





$E_{input} = \frac{1}{2}\frac{T}{2}V\cdot I + \frac{1}{2}\frac{3}{2}V\cdot\frac{I}{\cancel{2}}\,\cancel{2}I$

$E_{input} = \frac{1}{4}VIT + \frac{3}{4}IVT = VIT$

at $t = tP$

$E_b = QP$

the drop on limiting resistance $= QR$

$P_{loss} = 2IQR$

$E_{loss} = \Delta OCB \xrightarrow{\text{volt-time}} * 2I$

$= 2I(0.5VT)$

$E_{loss} = IVT$

input energy to motors $=$

$= 2I * \Delta OBB'$

$= 2I * (0.5VT)$

$E_{inp} = IVT$ (out)

$\eta_{notch} = \frac{P_{out}}{P_{in}} * 100 = \frac{P_{out}}{P_{out} + P_{loss}}$

$\eta_{notch} = \frac{IVT}{IVT + IVT} = 0.5$

$\eta_{notch} = 50\%$

$\therefore \eta_{s.p} > \eta_{notching}$

at $t = tN$ the motor connected parallel

$E_b = MN$ and drop on $R = M$

- in series mode the losse

$E_{loss} = I * \Delta OCB'$

at $t = tN$ motors switched in parallel so Eloss equal

$E_{loss} = 2I\Delta MB'B$

$E_{loss} = I * \Delta OCB' + 2I\Delta MB'B$

$= I(0.5VT/2) + 2I(\frac{1}{2}\frac{V}{2}T/2)$

$E_{loss} = 1/2\,VTI$

Eloss notch > Eloss (S/P)

$\eta_{s.p} = \frac{IVT}{IVT + 1/2\,IVT}$

$\eta_{s.p} = 66\ 2/3\ \%$

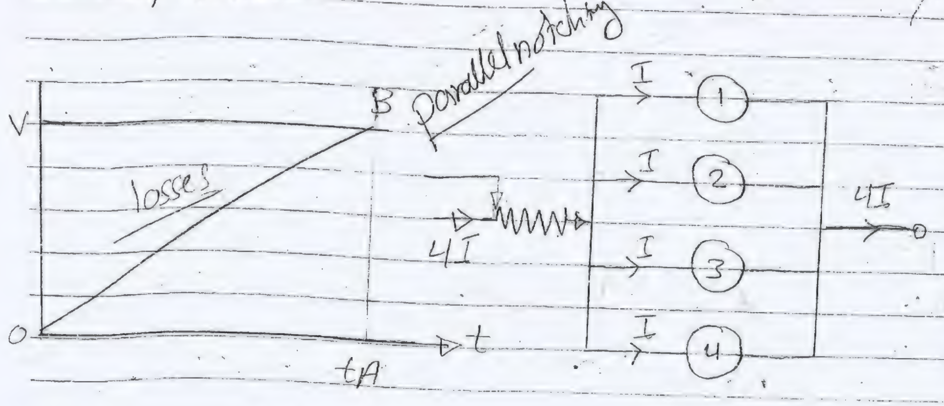
* Energy wasted in series parallel is half that in notching

Ex there are 4 motor in train its desired to use a series Parallel method to as follows.

[1] series [2] series parallel [3] Parallel Combination

there are 3 speed whose rating 1:2:4

Compare between thus method and notching method of starting from efficiency and energy loss point of view.



$E_{losses} = 4I * \Delta OCB$

$= 4I * (\frac{1}{2} VT)$

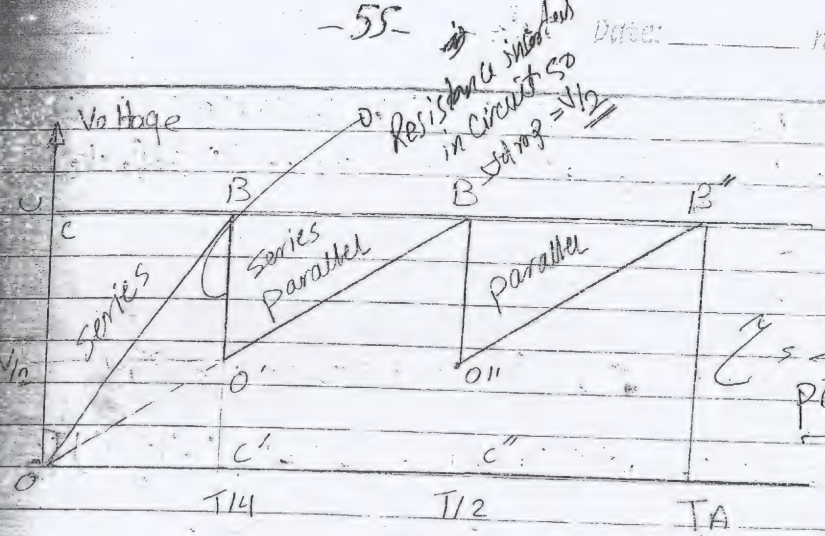
$E_{losses} = 2IVT$

$E_{inp} = 4I * \Delta OBm$

$= 2IVT$

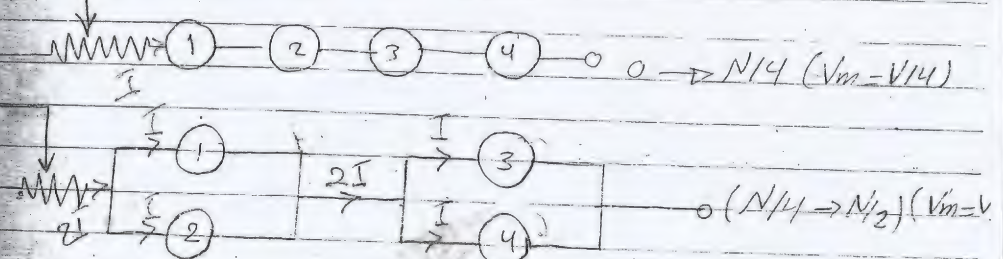
$\eta_{notch} = \frac{E_{out}}{E_{out} + E_{loss}} = \frac{2IVT}{2IVT + 2IVT} = 50\%$

$\eta_{notch} = 50\%$



$\eta = \frac{PO}{PO + P_{loss}}$

$P_{i/p}$

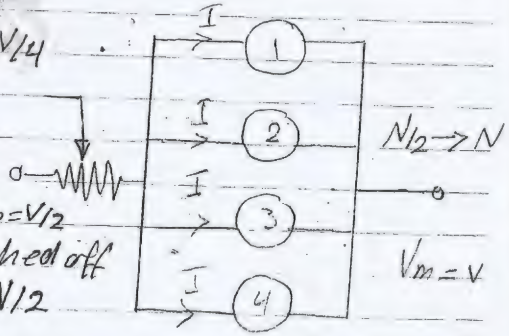


- in series

each motor have V/4 c eb = V/4 and rotate to N/4

- in series parallel

we inserte resistance so Voltage on motor V/2 and eb = V/2 the resistance is switched off gradually. so motor rotate N/2



- in paralle.

inserte resistance and switched of gradually so the voltage on motor is V and rotate "N"

$E_{loss} = I\Delta OCB + 2I\Delta O'BB' + 4I\Delta O''BB''$

$= I(0.5VT/4) + 2I(0.5V/2\ T/4) + 4I\{V/2 * T/2 * 1/2\}$

$E_{losses} = 0.75\ IVT$

input energy:

$= I\Delta OBC' + 2I[O'B'C''C'] + 4I[\text{area } C''O''B''M$

$= I(0.5V\ T/4) + 2I\left(\frac{V+0.5V}{2} * T/4\right) + 4I\left(\frac{V+0.5V}{2}\right)T/2$

$= \frac{IVT}{8} + \frac{3}{8}IVT + \frac{3}{2}IVT$

$= 2IVT$

$E_{inp} = E_{out}$ of motors = Energy used

$$\eta_{sip} = \frac{E_{out}}{E_{in} + E_{loss}} = \frac{2IVT}{2IVT + 0.75IVT} = 0.73$$

$\eta_{sip} = 73\%$

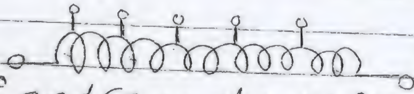
$\eta_{sip} > \eta_{notch}$ #

$$\frac{E_{loss}}{E_{used}} = \frac{0.75IVT}{2IVT} = 0.375$$

* **Field weakening or tapped field control:**

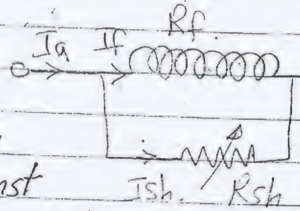
- using tapping

by tapping field winding to change If and so on change flux.



- using shunt resistance

the armature current is const but as Rsh change Ifsh change and so If change to have Ia = const



Ex

The following figures relate to a series wound motors of an electric locomotive.

Current per motor (A)	200	300	400	500
train speed (m.p.h)	41.5	33.5	28.5	28.0
Tractive effort / motor (Ib)	1300	2460	3660	4870

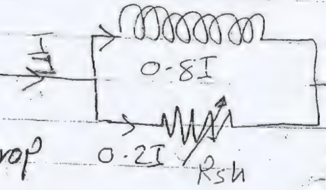
Calculte the value of speed and T.E for the same range armature current when a series field current reduced by 20% by a field diverting resistance.

ST

$I_{f new} = 0.8\ I_{f old}$

$V = E + I_a r_a$

$e = E = K\phi N$ neglect valte drop



if supply valte is const $N \propto \frac{1}{\phi}$, $\phi \propto I_f$

Date: ______ no: ______

the relation between speed and current it isnot Linear.

I_a = const $\quad I_a = I_f \downarrow + I_{fsh} \uparrow$ = cons

at $I_a = 500A \Rightarrow I_{fnew} = 0.8 * 500 = 400\ A \Rightarrow N = 28.5$

at $I_a = 400A \Rightarrow I_{fnew} = 0.8 * 400 = 320A \Rightarrow N = 32$

at $I_a = 300A \Rightarrow I_{fnew} = 0.8 * 300 = 240A \Rightarrow N = 38$

at $I_a = 200A \Rightarrow I_{fnew} = 0.8 * 200 = 160A \Rightarrow N = 45.$

$N \alpha \frac{1}{I_f}$ من الممكن نزيد قيمة السرعة عن طريق تقليل (If)

* $T.E \,\alpha\, I\phi \quad , \phi \,\alpha\, \frac{1}{N} \Rightarrow T.E \,\alpha\, \frac{I}{N}$ at const E

- relation between T.E and I_a from curve is nearly Linear So

$$T.E_{new} = T.E_{old} * \frac{N_{old}}{N_{new}}$$

at $I_a = 500A$

$$T.E|_{500} = 4870 * \frac{28}{28.5} = 4784.56 \downarrow (ib)$$

at $I_a = 400A$

$$T.E|_{400} = 3660 * \frac{28.5}{32} = 3260 \downarrow ib$$

لأن السرعة زادت

at $I_a = 300A$

$$T.E|_{300} = 2460 * \frac{33.5}{38} = 2168 \downarrow (ib)$$

at $I_a = 200A \Rightarrow$

 Date: ______ no: ______

$$T.E|_{200} = 1300 * \frac{41.5}{45} = 1198.9 \downarrow (ib)$$

- Draw the new Curves.

Current per motor (A)	200	300	400	500
trainspeed (m.p.h)	45	38	32	28.5
tractive effort permotor	1198.9	2168	3260	4784.56

* find an expression for specific energy consumption (S.E.C)

$$S.E.C = \frac{\text{energy consumption (w.hr)}}{W.S}$$

W ⇒ dead weight , S ⇒ length of train

$$S.E.C \text{ for acceleration} = \frac{1/2\ P_a\ t_a}{W.S}$$

$$S.E.C\,A = \frac{1/2\,(0.002) * 102\, W_e \alpha V\ V/\alpha}{W.S} \quad \frac{Kw.sec}{ton\ mil}$$

$$= 0.102 \frac{W_e V^2}{W.S} \quad Kw.sec / ton\ mile$$

$$S.E.C\,A = 0.028 \frac{W_e V^2}{W.S} \quad w.h / ton\ mile$$

Energy Consumption for acceleration $= \frac{1}{2} Pata$

$$= \frac{1}{2} Pata = 0.028\, we\, V^2 \quad (w.h)$$

[2] S.E.C for overcome train resistance.

$$S.C.CR = \frac{2 Fr_s S'}{w_s} = \frac{2 w r_s S'}{w_s}$$

$$SECR = 2r \frac{S'}{S} \quad (w.h / ton.mile.)$$

where

$S' = \frac{1}{2} ta\, Vm + tc\, Vm \rightarrow$ free runing

$S' = \frac{1}{2} ta\, Vm \rightarrow$ without free runing

energy consumption for resistance $= 2 Fr_s S'$ (w.h)

[3] SECG (energy consumption to over come gradiant gravity)

$$S.E.CG = \frac{2 Fg S'}{w_s}$$

$$= \frac{\pm 2 \times 22.4\, W G' S'}{W_s}$$

$$SECG = \pm 44.8 \frac{G' S'}{S}$$

$G' = 100 \sin\theta$

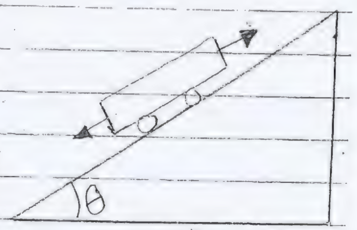
- energy consumption for gradiant gravity

$$= 2 Fg S' \quad (w.h)$$

Sheet (1)

(6) 2 stations, 1 mile part, $S = 1.0$ mile, $V_{av} = 25$ m.p.h u.., $= 27.5$ m.p.h d..

died weight = 210 tons
acceleration = 1.2575 m.p.h.p.s
braking retardation = 2 m.p.h.p.s
net T.E = 30000 Ib up
" " = 47 000 Ib down
r = 12 Ib
we = 1.1 w



- assume both direction made to trapezoidal speed time curve and determine without free Run.

«Solution»

Specific energy output = specific energy consumption

S.E.C = energy need to accelerate train
+ " " " over come " resistance
+ " " " " " gravity

acceleration	retardation
$ft = fa + fr + fg$ up $\rightarrow a_{up}$	$ft = fa - fr - fg$ up $\rightarrow b_{up}$
$ft = fa + fr - fg$ down $\rightarrow a_{do}$	$ft = fa - fr + fg$ down $\rightarrow b_{do}$

① S.E need to accelerate the train

$$S.E.C.A = \frac{1/2\, P a t a}{w.S}$$

$$= \frac{1}{2}\,\frac{0.002 f a V\, V/a}{w.S}$$

$$\boxed{S.E.C.A = 0.028\,\frac{W e V^2}{w.S}}$$ w.h/ton mile

② S.E need to overcome the train resistance

$$S.E.C.R = \frac{2 f r S'}{w.S} = \frac{2 r S'}{S}$$ # w.h/tonmile

$S' = 0.5\, t a V m + t c V m$

$S' = 0.5\, t a V m$

③ S.E need to overcome gradiant gravity

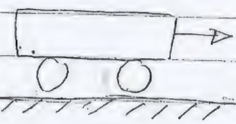
$$S.E.C.G = \frac{2 f g S'}{w.S} = \frac{\pm 2 * 22.4 W G' S'}{w.S}$$

$$S.E.CG = \pm 44.8\,\frac{G' S'}{S}$$ #

acceleration a = 1.2575

$fa = ft - fr - fg \to 0$

$fa = ft - fr = 30000$



braking b = 2 m.p.h.p

$fb = ft + fr - fg \to 0 \Rightarrow 47000$

1) For acceleration the train

$fa = ft - fg - fr$

$102 We\, \alpha up = ft - fg - fr$

$$\alpha up = \frac{ft - fg - fr}{102 We} = \frac{30000 - (22.4 * 210 * \frac{100}{80})}{102 * 231}$$

$\alpha up = 1.02$ [m.p.h.p.s]

$$\alpha down = \frac{ft + fr + fg}{102 We} = \frac{30000 + (22.4 * 210 * \frac{100}{80})}{102 * 231}$$

$\alpha down = 1.523$ m.p.h.p.s

$fb = fT - fr - fg$

$$b = \frac{ft + fr - fg}{102 We}$$

$$bup = \frac{ft + fr + fg}{102 We} = \frac{47000 + (22.4 * 210 * 100/80)}{102 * 231}$$

$bup = 2.244$ m.p.h.s

$$bdown = \frac{ft + fr - fg}{102 We} = \frac{47000 - (22.4 * 210 * 100/80)}{102 * 231}$$

$bdown = 1.745$ m.p.h.p.s

$$V_{up} = \frac{1}{2k}\left[T - \sqrt{T^2 - 14400\,Sk}\,\right]$$

$$K_{up} = \frac{1}{2\alpha_{up}} + \frac{1}{2b_{up}} = \frac{1}{2*1.02} + \frac{1}{2*2.244}$$

$K_{up} = 0.713$

$$V_{av} = \frac{S}{T_{up}}, \quad T_{up} = \frac{S}{V_{av}} = \frac{1}{25} = 144\ \text{sec}$$

$V_{up} = 29.23$ (m.p.h)

* $T_{down} = \dfrac{1}{27.5} = 0.036\ \text{hr} = \boxed{131\ \text{sec}}$

$$K_{down} = \frac{1}{2\alpha_d} + \frac{1}{2b_{down}} = \frac{1}{2*1.523} + \frac{1}{2*1.745}$$

$\boxed{K_{down} = 0.615}$

$$V_{down} = \frac{1}{2*0.615}\left[131 - \sqrt{131^2 - 14400*0.615*1}\,\right]$$

$V_{down} = 32.4$ (m.p.h)

$t_{a\,up} = \dfrac{V_{aup}}{a_{up}} = 28.65$	$t_{a\,down} = 21.27$ sec
$t_{b\,up} = 13.025$	$t_{b\,down} = 18.567$ sec
$t_{c\,up} = T - t_a - t_b = 102.3$	$t_{c\,down} = 91.2$ sec

* for up gradiant direction

$$S.E.C.A = 0.028\,\frac{W_e V^2}{W.S} = 0.028 * \frac{231*29.23^2}{210}$$

$S.E.C.A = 26.3$ w.h/ton mile

$$S.E.C.r = \frac{2rS'}{S} = \frac{2r * (1/2\,t_a\,V)}{S}$$

$$S' = 1/2\,\frac{29.23^2}{3600*1.02} = 0.11\ \text{Mile}$$

$$= \frac{2*12*28.65*29.23}{2*3600} = 2.8\ \text{w.h/tonmile}$$

$$S.E.C.g = +44.8\,\frac{G'S'}{S} = 44.8 * \frac{100}{80} * 0.5 * \frac{28.65*29.2}{3600}$$

$= 6.5$ w.h/ton mile

$S.E.C = 6.5 + 2.8 + 26.3 = 35.6$ w.h/ton mile

* for down gradiant direction

$$S.E.C.A = 0.028\,\frac{W_e V^2}{W.S} = 32.3\ \text{w.h/ton mile}$$

$$S.E.C.r = \frac{2rS'}{S} = 2.3\ \text{w.h/tonmile}$$

$S' \rightarrow 0.0957$ Mile

$$S.E.C.g = \ominus 44.8\,\frac{G'S'}{S} = \ominus 5.36\ \text{w.h/tonmile}$$

$S.E.C = 29.2$ w.h/ton mile

[7] $W = 250$ ton, $S = 1.25$ mile, $V_{av} = 32$ m.p.h

$a = 1.25$, $b = 2.3$, $r = 12$ Ib

$W_e = 1.1 * 250 = 275$ ton, mainline service.

- assume trapezoidal speed-time curve.

Calculate the energy consumption for the run.

الحل

$$S.E.C = S.E.C_a + S.E.C_r + S.E.C_g$$

- $S.E.C_a = 0.028 \dfrac{W_e V^2}{W S}$

$V_{av} \Rightarrow \dfrac{S}{T} \Rightarrow T = \dfrac{S}{V_{av}} = \dfrac{1.25}{32} = 140.6$ sec

$K = \dfrac{1}{2a} + \dfrac{1}{2b} = \dfrac{1}{2*1.25} + \dfrac{1}{2*2.3} = 0.617$

$V = \dfrac{1}{2k}\left[T - \sqrt{T^2 - 14400\, Sk}\right]$

$= \dfrac{1}{2*0.617}\left[144 - \sqrt{144^2 - 14400*1.25*0.617}\right]$

$V = 38.51$ (m.p.h)

$S.E.C_a = 0.028 \dfrac{275*38.51^2}{250*1.25} = 36.56$ w.h/tonmile

$S.E.C_r = \dfrac{2 r S'}{S} = \dfrac{2*12*(1/2\, t_a V)}{S}$

$t_c = T - t_a - t_b = T - \dfrac{V_m}{a} - \dfrac{V_m}{b}$

$S' = \frac{1}{2} \frac{30.48*38.51}{3600} = 0.1648$

$t_a = \dfrac{V_m}{a} = 30.48$

$t_b = \dfrac{V_m}{b} = 16.56$

$t_c = 93.56$

$S' = 1.151$

$S' = \frac{1}{2}\frac{t_a V_m}{3600} + t_c V_m$

$t_c = 140.6 - \frac{V_m}{a} - \frac{V_m}{b}$

93

553.5

mile $= 1.159$ S'

$* WS$

$+ t_c V_m$

$S.E.C_r = 22.25$ w.h/tonmile

$S.E.C_r = \dfrac{\frac{1}{2}(29.76*37.2)*\frac{24}{3600}}{1.25} = 22.25$ w.h/ton

$S.E.C_t = 22.25 + 36.56 = 58.81$ (w.h/tonmill)

energy consumption $= 58.81 * W * S *$

$E.C = 58.81 * 250 * 1.25 = 18378.2$ w.h

[12] given $S = 1.2$ mile, $W = 200$ ton

$V_{sch} = 25$ m.p.h, $W_e = 220$ ton

$t_s = 20$ sec, $r = 10$ Ib/ton

$\beta_c = 0.1$, $b = 2$

$V_1 = 38$ m.p.h

- assume ~~trape~~ quadrilateral speed-time curve

- required:

1- S.E output for the run

2- the energy disspated during coasting

3- " " " brakes

4- mean train resistance during coasting.

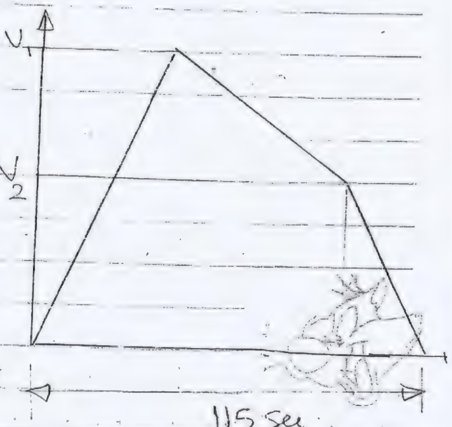
الحل

$V_{sch} = \dfrac{S}{T + t_{stop}}$

$T + t_s = \dfrac{S}{V_{sch}} = \dfrac{1.2}{25}$

$= 172.8$ sec

$T = 172.8 - 20 = 152.8$ sec



$bc = \frac{V_1 - V_2}{ts}$ تكملة مس 1

$U_2 = U_1 - bc\,tc$

$U_2 = 38 - 0.1tc \rightarrow$ ●

$tb = \frac{V_2}{b} \Rightarrow V_2 = b\,tb \rightarrow$ ●

$\therefore tb = 19 - 0.05tc$ from k2

$ta = T - \cancel{tc} - tb$

$ta = 150.2 - 19 + 0.05tc - tc$

$ta = 131.2 - 0.95tc \rightarrow$ ●

$$S = 1.2 = \frac{1}{7200}\Big[\overbrace{4985 - 36tc}^{sa} + \overbrace{(76 - 0.1tc)tc}^{sc} + \overbrace{(38 - 0.1tc)(19 - 0.05tc)}^{sb}\Big]$$

$8640 = 4985.6 - 36tc + 76tc - 0.1tc^2 + 722 + 0.005tc^2 - 3.8t$

$8640 = 0.095tc^2 + 36.2tc + 5707.6$

$0.095tc^2 - 36.2tc + 2932.4 = 0$

$tc^2 - 381.05tc + 30867.368 = 0$

$tc_1 = 264.229$ sec , $tc = 116.82$ sec ✓

$ta = 20.24$ sec

$tb = 13.16$ sec

$U_2 = 26.32$ sec

$$S.E \text{ out for the run} = 0.0283 * \frac{V_1^2}{S}\frac{we}{w} + 2(r + 22.4G_i')\frac{S'}{S}$$

$$= 0.0283 * \frac{38^2}{1.2}\frac{220}{200} + 2(10 + 0) * \frac{0.5 * 38 * 20.24}{3600 * 1.2}$$

37.45 1.78

$G_i' = 0$

$\frac{1}{2}$ ta V/m

$S.E.C = 39.96$ (w.h / ton mile)

sec m / 3600 ... 1.25

(b) energy dissipated during coasting

$$E = \frac{1}{2}weV_1^2 - \frac{1}{2}weV_2^2 -$$

$$= \frac{1}{2}220 * (38)^2 - \frac{1}{2} * 220 * (26.32)^2 = 82383 \text{ (w.h)}$$

(c) energy dissipated during braking

$$E = \frac{1}{2}weV_2^2 = 76201.66 \text{ w.hr}$$

(d) mean ~~train~~ resistance during coasting

$$bc = \frac{-fr - fg^{\,0}}{102we} = \frac{-fr}{102we}$$

$$-0.1 = \frac{-wr}{102we}$$

$wr = 2244$ Ib.wt

$r = 11.22$ Ib/ton

[13] $w = 200$ ton, gross T.E $= 25000$ Ib, $S = 0.8$ mile
$T = 120$ sec, up gradiant, $r = 10$, $we = 1.1\,w$
$b = 2.2$

- required
  Determine the maximum speed attained
- energy supplied to the driving wheels.

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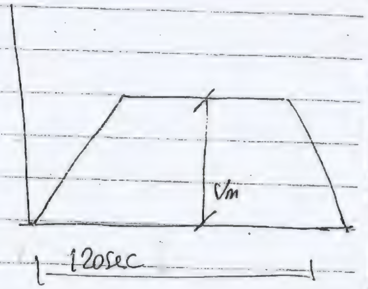
$$fa = ft - fr - fg$$

$$102\,we\,a = ft - fr - fg$$

$$a = \frac{ft - Wr - 22.4\,W\,Gi'}{102\,we}$$



$ft \Rightarrow$ gross tractive effort $= 25000$ Ib

$$fr = Wr = 200 * 10 = 2000 \text{ Ib.wt}$$
$$fg = 22.4\,W\,Gi' = 22.4 * 200 * \frac{100}{100} = 4480 \text{ Ib.wt}$$

$$K = \frac{1}{2a} + \frac{1}{2b} = \frac{1}{2*0.825} + \frac{1}{2*2.2}$$

$$K = 0.833$$

$$V = \frac{1}{2K} * \left[T - \sqrt{T^2 - 14400 * S * K}\right]$$

$$V = \frac{1}{2*0.833}\left[120 - \sqrt{120^2 - 14400 * 0.8 * 0.833}\right]$$

$$V_{max} = 30.426 \text{ m.p.h}$$

$$SEC = 0.028\,\frac{V^2}{S}\,\frac{We}{W} + 2\,(r + 22.4\,Gi')\,\frac{S'}{S}$$

$$SEC = 0.0283 * \frac{(30.426)^2}{0.8} * \frac{220}{200} + 2(10 + 22.4*1)\,\frac{S'}{S}$$

$$S' = \frac{1}{2}\,t\,a\,V_m = \frac{1}{2}\,\frac{V_m^2}{a} = \frac{561.055}{3600} \text{ mile} = 0.155$$

S.E.C = ~~[illegible]~~ 48.81 (w.h/mile ton)

energy supplied to driving wheel = S.EC * W.S

= ~~[illegible]~~ wh 7808.0 wh

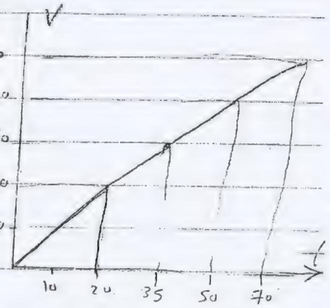
$\boxed{10}$ $t = 70$ sec

Time (sec)	0	10	20	35	50	70
speed m.p.h	0	10	20	30	40	50
τ	0.25	0.18	0.14	0.12	0.10	0.09

- find U_{av}, τ_{av} ??
- find maximum acceleration

اكل

- Draw $(U-t)$, $(\tau - t)$



$U_{av} = \dfrac{S}{T}$ (area under curve)

$S = \int v\,dt$

$$= \frac{1}{70}\left[\overset{200}{0.5(20*20)} + \overset{375}{0.5(20+30)*15} + \overset{900}{\tfrac{1}{2}(40+50)*20}\right] + 0.5(30+40)*15$$

$U_{av} = 28.67$ [m.p.h]

$\tau_{av} = \dfrac{\text{area}}{T}$

$$= \frac{1}{70}\Big[0.5(0.25+0.18)*10 + 0.5(0.18+0.14)*10$$

$$+ 0.5(0.14+0.12)*15 + 0.5*35(0.12+0.09)\Big]$$

$\tau_{av} = 0.1339$

$f_t = \tau_{ad} * W$

$\cancel{m} * a = \tau_{ad} * \cancel{m} * 32.2$ ft/sec.sec

$a = 0.25 * \dfrac{32.2 * 3600}{5280}$ m.p.h.p.s

* Starting of Ac Motors and speed Control.

[1] 3 phase Induction motor.

- for slip ring rotor Starting is done by liquide or metallic rheostats in rotor Circuit.

Speed Contorl

rotor resistance | Cascading | pole changing.

① rotor resistance

$$S = \frac{N_s - N}{N_s} = 1 - \frac{N}{N_s}$$

$$\frac{N}{N_s} = 1 - S, \quad N = (1-S)N_s \quad N = \frac{60f}{P} \text{ rpm}$$

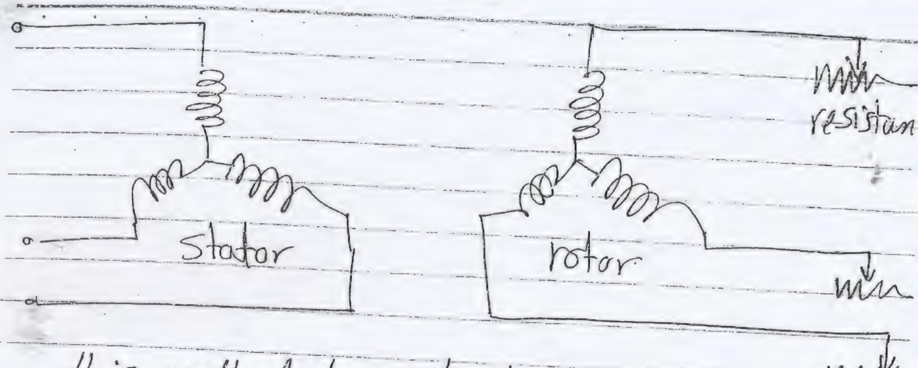
$$N = \frac{f}{P} \text{ rps}$$

$$N = (1-S)\frac{f}{P}$$ change f, P, S to change speed

rotor cupper loss $= S P_g = S K \frac{f}{P} T$ → torque

if rotor cupper loss changed S → change so N change

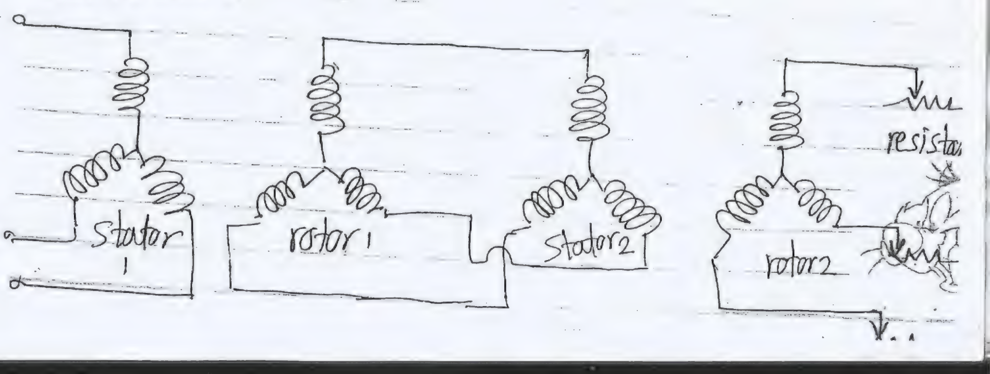
So we use resistance into rotor Circuit to Speed control.



- this method hase high (wastefull) losses (large copper losses) ⇒ more heat so th power can be used to operate another I.M Cascading

[2] Cascading I.M

- instead of Power wasted into resistance this po can be used to operate another I.M by Cascading Connection



- disadvantages

1- low power factor of Combination

2- require 2 3phase I.m

* the power is taken by a slip ring of the first motor to drive the second motor (SPg).

the reheostat in the second motor enable speed regulation up to the cascade Synchronous Speed

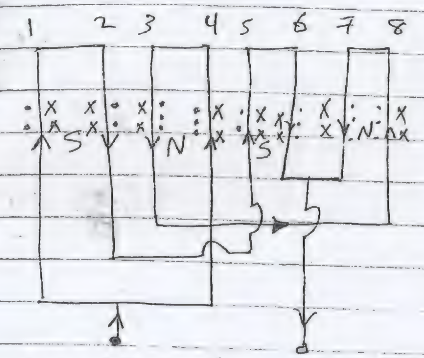
$P_1 = SP_2$ Pairs of poles

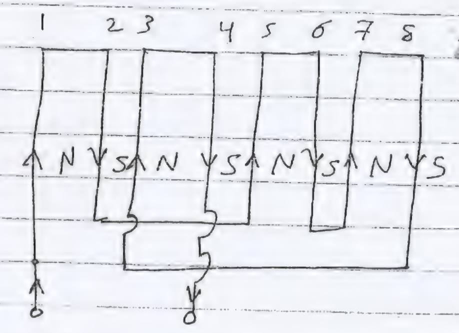
$N = \frac{120f}{P_1 + P_2}$ rpm

tow motors are coupled Mechanically

If $P_1 = P_2$, $N = \frac{120f}{2P_1}$ so N half one motors speed, and 2 motor provide equal mechanical power.

3 Pole changing:





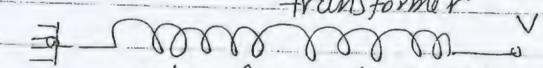
* 4 pole winding * 8 pole winding

$N = (1-S)\frac{120f}{P}$ as No of pole changed the speed changed

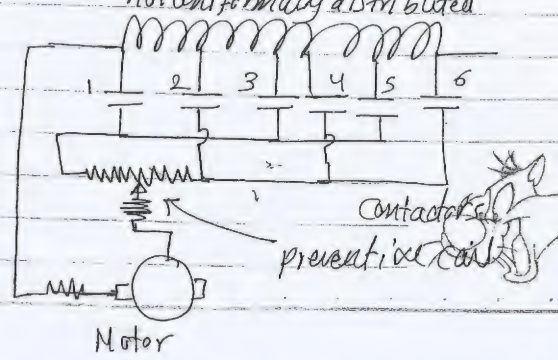
- winding is connected to give 4 and 8 poles by altering supply connection

* Single phase Induction motor:

1- tapping exchange



Notch	Contactor 1	2	3	4	5	6
1	X	X				
2		X	X			
3			X	X		
4				X	X	
5					X	X



- there are five notch at each position two Contactors are closed.
- the Volt Can be reduceing at Start without aresistance so large sawing in energy.
- the motor take its power from transformer secondary through tap exchange by acontactors.

* Preventive coil:-

- to ensure proper operation to prevent Short circuit at transformer secondary.
- at each notch there are two contactor closed.

* advantages:-

- each notch is aRuning position so wide speed change
- low losses because high efficiency transformer.

* Electric braking

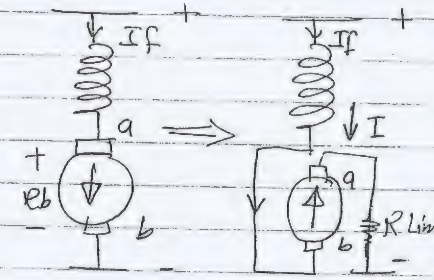
plugging — rheastatic — regenerative

- in certain train there are mechanical or electric wheal brakes.

1) plugging:-

- in plugging the torque is reversed by reverse of armature current or field current.

but not (both). its better to current (I_a) this for dc Motor.



* it has high copper loss in series resistance. for three phase I.M plugging can happen by reversing direction of rotation of magnetic field by reversing one phase.

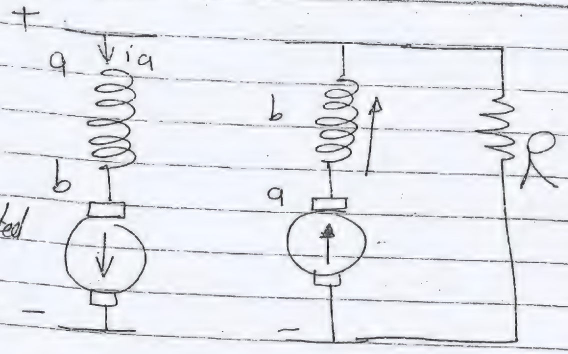
$$I = \frac{E + e_b}{R_a + R_{Limit}}$$

- Construction is Simple (advantages).

2) rheastatic braking:-

the motor is disconnected from the supply and Connected to aresistance
the kinetic energy that motor gain through Running is dissipated through resistance and motor act as generator

- in electric traction there are 2 or 4 motors when we connected in series and rheostatic brak is applied the total voltage will be large so we should connected it parallel to make brake.



So these motor should shared load equally.

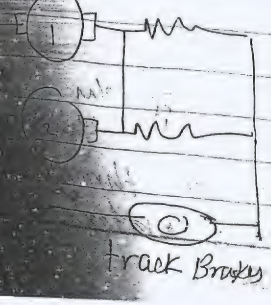
* problem during this:

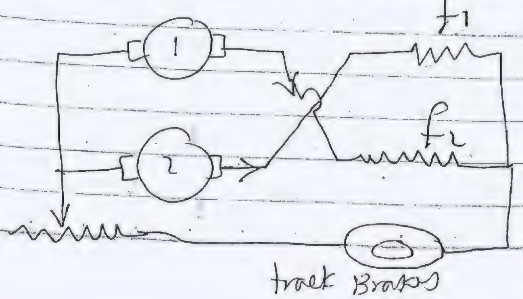
one machine do build up fastly than other machine so a short circuit may happen.

- there are 2 method to avoid short circuit condition

1- using on equilizing bar

2- across connection of the field





- The armature current of the more power full excited machine (fast buildup) increase the field of the less powerfull excited machine so the 2 M/cs have equal excitation.

* advantages:

1- low loss in energy because there isn't energy drawn from supply at braking.

rheostatic braking is better than plugging because plugging has much loss (energy from supply = VI and the internal energy has to be dissipated into series resistance so it has much wast in energy).

2- simple in construction.

* Regenerative Braking:

* advantayes and disadvantges of regenerative Braking on level route ??

* disadvantages:

1- So far as dc equipments are concined are briefly.
2- the motors are larger, heavier and more cost than ordinary equipments.
3- increase the maintenance chargs on the electrical equipment
4- Control and operation become Complicated.
5- increase weight of the train and No of motor
6- additional equipment to control the regenerative action of the motors.

* advantage:

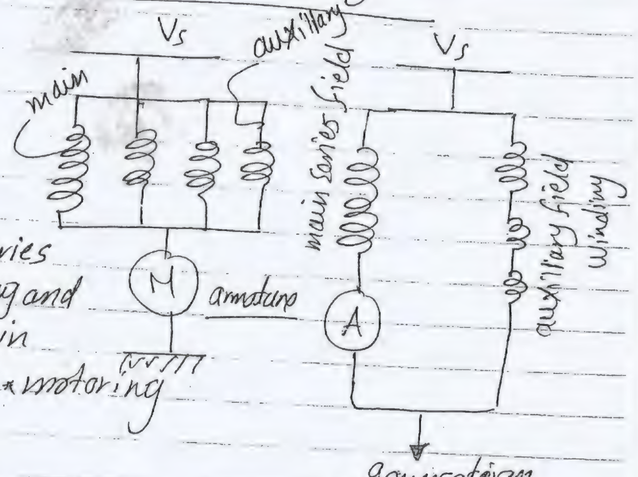
1- reduce energy Consumption
2- " wear or brake shoes and wheel tyres so lower maintanenca cost of these parts.
3- Small amount of brake dust produce when the mechanical brakes is applied.
4- reduction of energy consumption reach to 10% on level route but in undulating routs the saving may reach to 20%.

* Electric Regenerative on main line and mountain Railways is essential due to:-

1- the large amount of energy available during the descent of the gradiants.
2- the large use of electric locomotives
3- the operating Conditions permitting the use of motor having aconstant speed characteristices.
4- the runing cost have to be found to be only about 75% of those when the lines were operated with steam locemotive through down gradiants.
5- the recoperated energy being in order of from (60-80 of the energy Consumption for the up Journey with the same train.

French method of Regenerative braking:

- for one motor



* during motoring:
- the machine act aseries motor the field winding and auxillary winding are in Parallel with it

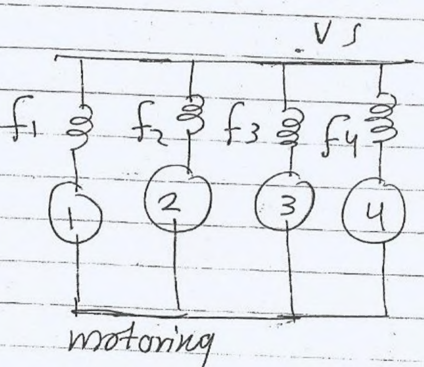
* during generation:
- the auxillary winding are switched in series and the machine act as a shunt generation.

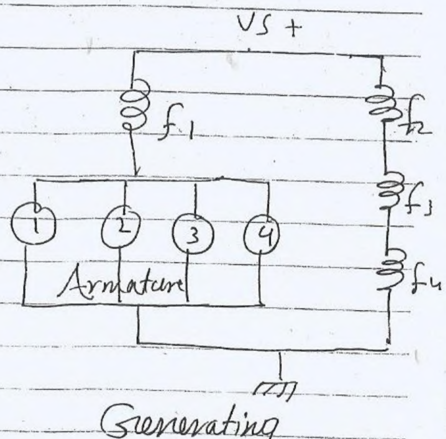
* For several motor:-

- during motoring: the field windings are in series with their own armature
- during generation: the motor circuit are in parallel (all armature in parallel)

- in series with one field winding and other field winding work as auxillary winding (in series) parallel to one field winding and motor circuit.

* assume four motors:





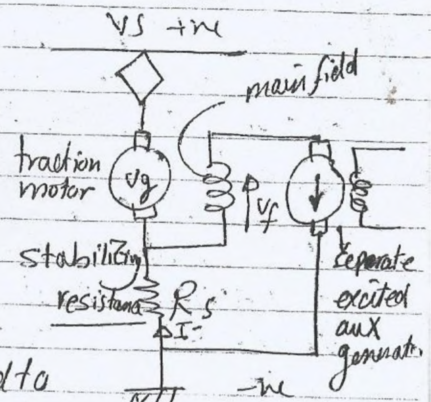
- the auxiliary winding connecting across the supply to help the main field winding to do build up fastly to return power to supply through braking.

* advantage:-

- there is not need any for auxiliary winding because some field winding ~~operate~~ do its operation.

[2] metropolitan_vickers regenerative system:-

- this system use an auxiliary generator it can be either one of train motor or special H/C
- the magnitude of the regenerative current is controlled by varying the field strength of auxiliary generator



- the stabilizing resistance is used to
  1- prevent current surges when the motor crosses from one section of supply to another.
  2- to compensate for variable line volt.

$$V_g = V_S + I'R_s$$

$$I'R = V_g - V_S$$

$$I' = I + I_{au}$$

$$V_{au} = V_f + I'R_s$$

V_{au} is const as a seperatly generator.

if V_s increase $\Rightarrow I \downarrow \Rightarrow I' \downarrow \Rightarrow I'R_s \downarrow \Rightarrow V_f \uparrow \Rightarrow V_g \downarrow$

* steps:-

- regenerative braking used down to about 10 m.p.h.
- the rheostatic braking down to 4 mph and finally mechanical braking untill stand still 0 m.ph

3 Metadyne:

علمي - it is a method of varying a volt by acheives smooth control of speed and starting of dc/M/C without dissipating energy in a resistance.

تعريف - its a rotating transformer for dc power with a variable turn ratio. so it can draw power from dc source and deliever it at a constant current and variable voltage to an accelerating motor.

- fig(a):
  ordinary machine with two poles and two brushes
- fig(b):
  metadyne with four pole and four brushes
  - $I_1 \Rightarrow$ produce primary flux
    this primary flux produce emf between (B, D) brushes.
  - I_2 flow through load.

fig(c): I_2 produce a secondary flux this secondary flux produce emf between (A, C) brushes which neutralize the applied voltage (E_1)

from fig(b) $E_2 = K I_1$ neglect loss
$E_1 = K I_2$

K -> constant depend on construction of M/C and speed

$E_1 I_1 = E_2 I_2$

input and output power are equal (like transformer)

if E_1 is const, I_2 = const and load resistance change

I_2 = const, I_1 increase and E_2 increase.

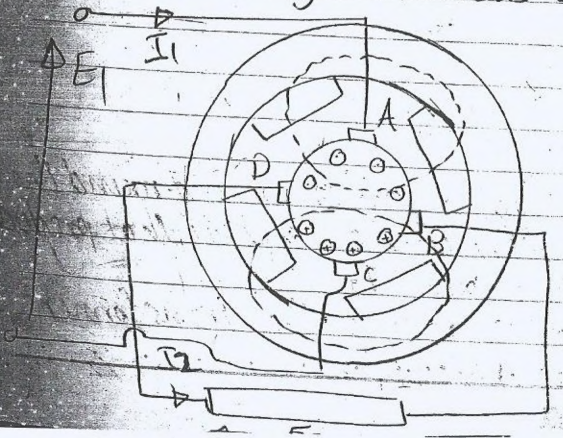
عندما يصل الموتور إلى السرعة max فإنه من الضروري أن يقل التيار

لـ I_2 rated value ولكن يتم هذا بواسطة

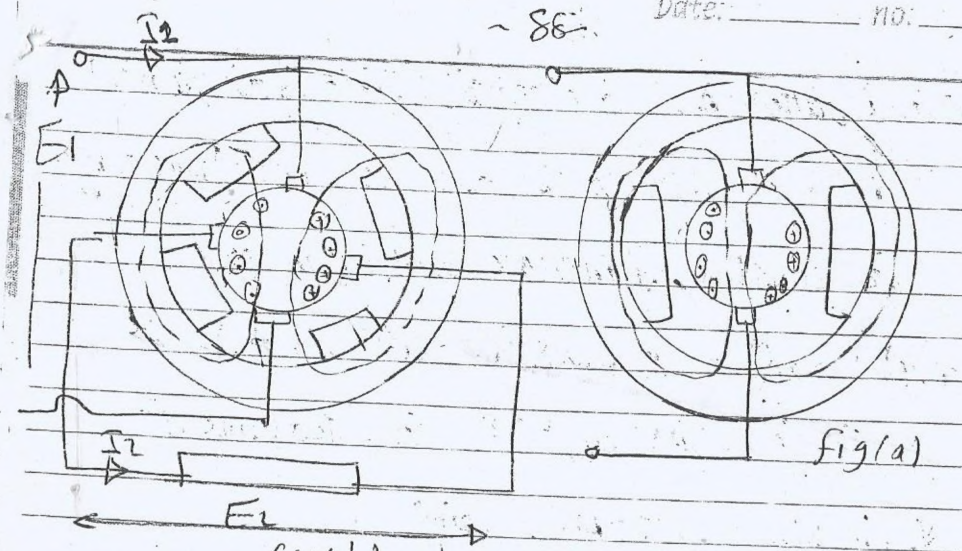
Variator or regular winding.

- advantage:
  - no switch require so there is no surge appear
  - low loss and high efficiency
  - giving constant current at start
  - smooth control without dissipating energy.

* disadvantages:
  - after beganing we can't reduce I_2 to be suitable for various load. so we used variator wdg

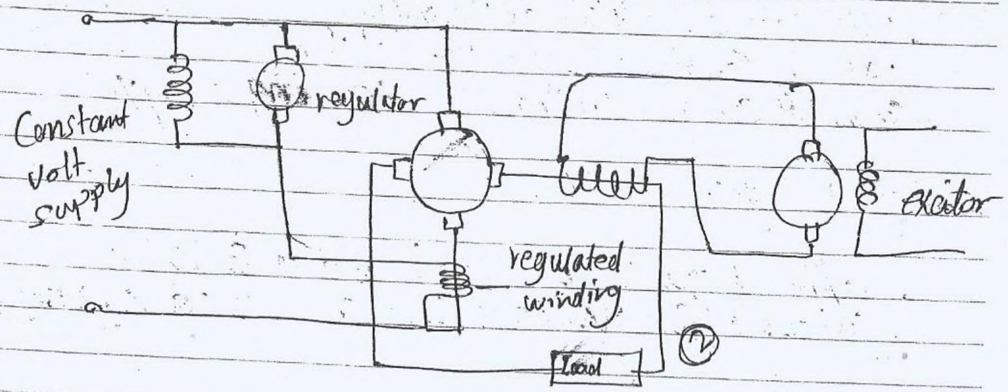


fig(c)



fig(b) fig(a)

* The Complete metadyne set.



- Variator winding:

- its a winding feed from dc exciter wound round the pole and produce of flux with or opposite that produced by I_2 so we can control I_2
- this a variator winding destroys the transformer property of the metadyne where.

$E_1 = K I_2 + k_v I_v$ (not transformer property)

when $I_v = 0 \Rightarrow E_1 = K I_2$ (transformer property)

+ve variator excitation when flux produced is in same direction that produced by I_2

(-ve) variator exciter when flux produced opposite direction of I_2 flux.

* regulator winding:-

- used to maintain metadyne it's transformer property
- it produce of flux this flux effect the output current and power output.
- if this regulator current is adjusted correctly the output power remains constant to input power

$E_2 = K I_1 + K_r I_r$

$I_r, I_v \rightarrow$ variator, regulator current
$k_v, K_r \rightarrow$ constant of M/C

$P_i = E_1 I_1 = K I_1 I_2 + K_v I_1 I_v$

$P_o = E_2 I_2 = K I_1 I_2 + K_v I_2 I_r$

to maintain transformer property we have

$P_i = P_o$

$E_1 I_1 = E_2 I_2 \Rightarrow K V I_1 I_V = K r I_2 I_r$

Ex 250 ton, mainline service $V_{avg} = 32$ Mi/h

$S = 1.25$, $a = 1.25$, $b = 2.5$ M.p-h.p-s

trapezoidal, E.C kwhr, $r = 12$, $\eta_{motors} = 80\%$

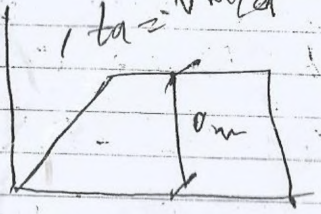
$W_e = 110\% \, w$, no free run,

Energy consumption = ??

$$\delta E.C = 0.028 \frac{W_e}{W} \cdot \frac{V_m^2}{S} + 2 \frac{S'}{S} \left[r \pm 22.4 G \right]$$

$$E.C = \left[0.028 \frac{W_e}{w} \frac{V_m^2}{S'} + \frac{2 r S'}{S} \right] \times WS$$

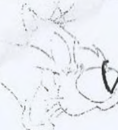
$S' = \frac{1}{2} t_a V_m$, $t_a = V_m / a$



$$V_m = \frac{1}{2K} \left[T - \sqrt{T^2 - 14400 S K} \right]$$

$K = \frac{1}{2a} + \frac{1}{2b}$, $T = \frac{S}{V} = \frac{1.25}{32/3600} = 50$

$V = S/t$



$$E.C = \frac{E.C'}{\eta_{motors}}$$